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THE APPARENT DEPTH OF OBJECT THROUGH LARGE ANGLE

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ABSTRACT
New approach to find the apparent depth was carried out in this work, with in mind taking large angle, instead of the usual small angles taken in this condition.

Two methods were carried out, the angle taken is about (> 10°).

KEYWORDS: refractive index, apparent depth, real depth.

INTRODUCTION
Most of the researches in optics, light and engineering optics used to find the apparent depth value of an object at depth (h) with refraction index (m') and depth (m) for small angles only. In this work we are going to find the apparent depth (h) for an object through large refractive angle through the medium where it is found where the refractive index is (m) through large angle (> 10°)[1,2].
In order to prove our theory, we used different ways to find the apparent depth.

The Theory
First we found the apparent depth for an object looking at through large angle
(> 10°). We found out the following[3,4].:

$$h = \frac{m}{m'} k \frac{\cos^3 x}{\cos^3 x'}$$, where h is apparent depth

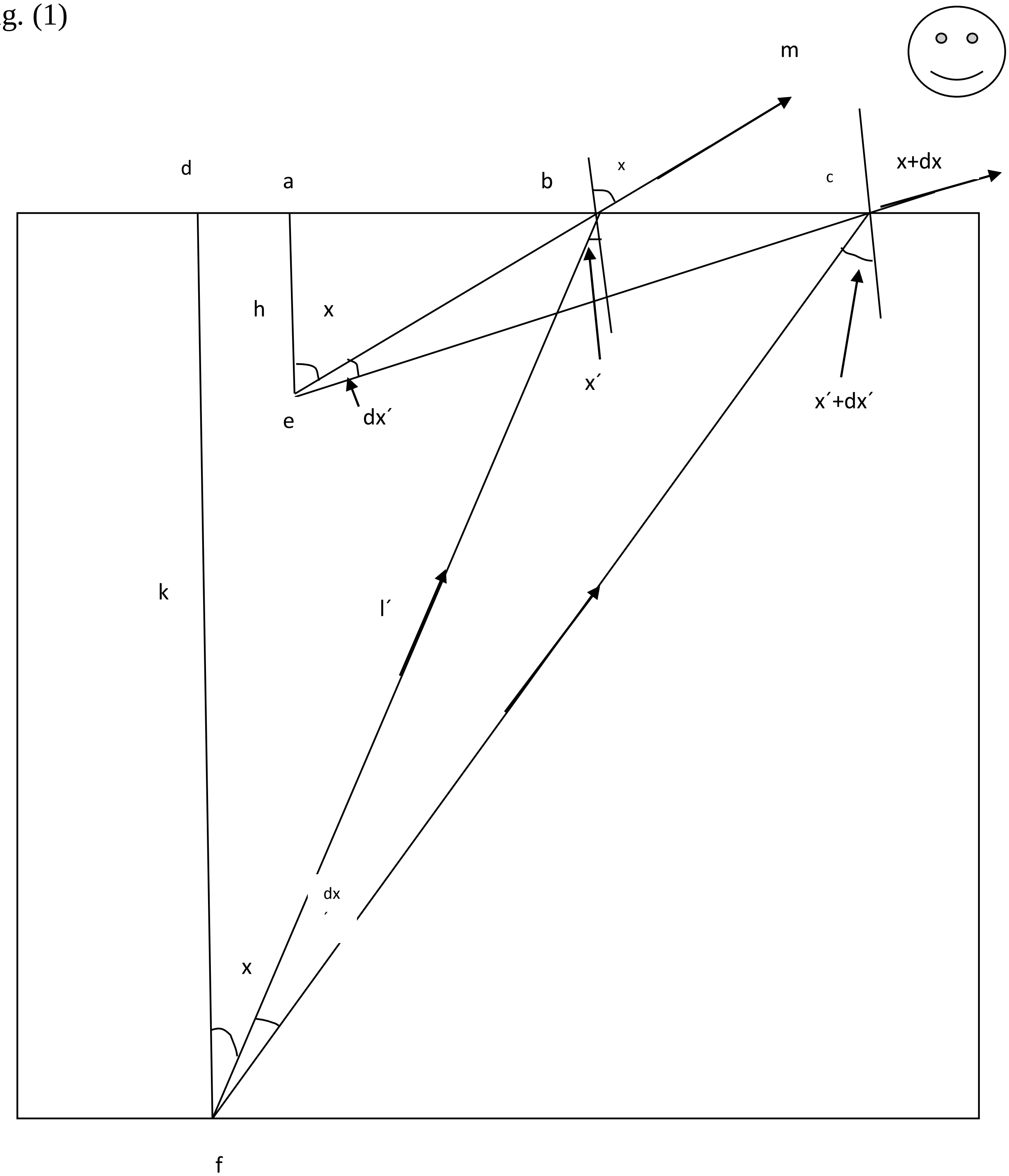
When the angle is very small the equation well be in the form:

$$h = \frac{m}{m'} k$$

The above equation represents the apparent depth law for small angles.

Method one
From the fig. (1) finding (bc) using (k) & (x′)

Fig. (1)



Let $\cos d\,x' = 1 \qquad , \sin d\,x' = d\,x'$

$$\frac{k}{n\,c} = \cos\,(\,x + x'd\,) = \cos x\,\cos\,x'd - \sin x\,\sin\,x'd$$

$$\frac{k}{n\,c} = \cos\,x' - \sin\,x'.\,x'd \qquad (1)$$

$$\frac{k}{n\,b} = \cos\,x' \qquad (2)$$

$$\frac{d\,c}{n\,c} = \sin(x' + x'd\,) = \sin x' \cos\,(x'd) + \cos x' \sin(x'\,d)$$

$$= \sin x' + \cos x'.\,x'\,d \qquad (3)$$

$$\frac{b\,d}{n\,b} = \sin\,x' \qquad (4)$$

$$\frac{k}{l'} = \cos\,x' \qquad (5)$$

$$bc = cd - b\,d = nc\,\left(\sin x' + \cos\,(x'\,)x'd\,\right) - nb\sin x'$$

$$b\,c = \frac{k\,(\,\sin x' + \cos x'\,.\,x'd\,)}{\cos x' - \sin x'.\,x'd} = \frac{k\,\sin x'}{\cos x'}$$

$$bc = \frac{k\left(\sin x'\,\cos x' + \cos^2 x'.x'd - \sin x'\,\cos x' + \sin^2 x'\,.\,x'd\right)}{\left(\cos x' - \sin x'.\,x'd\,\right)\cos\,x'}$$

$$bc = \frac{k\left(\,\cos^2 x' + \sin^2 x'\right)x'd}{\left(\cos x' - \sin x'.\,x'd\,\right)\cos\,x'} = \frac{k\,\,x'd}{\left(\cos x' + d\,\cos x'\,\right)\cos\,x'}$$

Method Two

$$bc = cd - b\,d = \left(l' + d\,l'\right)\,\sin(x' + x'd\,) - l'\sin x'$$

$$= \left(l' + d\,l'\right)(\,\sin x'\,\cos x'd + \cos x'\,\sin x'd\,) - l'\sin x'$$

$$= \left(l' + d\,l'\right)(\,\sin x' + \cos x'.\,x'd\,) - l'\sin x'$$

$$= l'\sin x' + l'\cos x'.\,x'd + l'\,d\sin x' + l'd\cos x'\,.\,x'd - l'\sin x'$$

$$= l'\,\cos x'.\,x'd + l'd\,\sin x'$$

From the fig. (1)

$$\frac{l'd}{cb} = \sin x' = l'\cos x'.x'd + cb\sin^2 x'$$

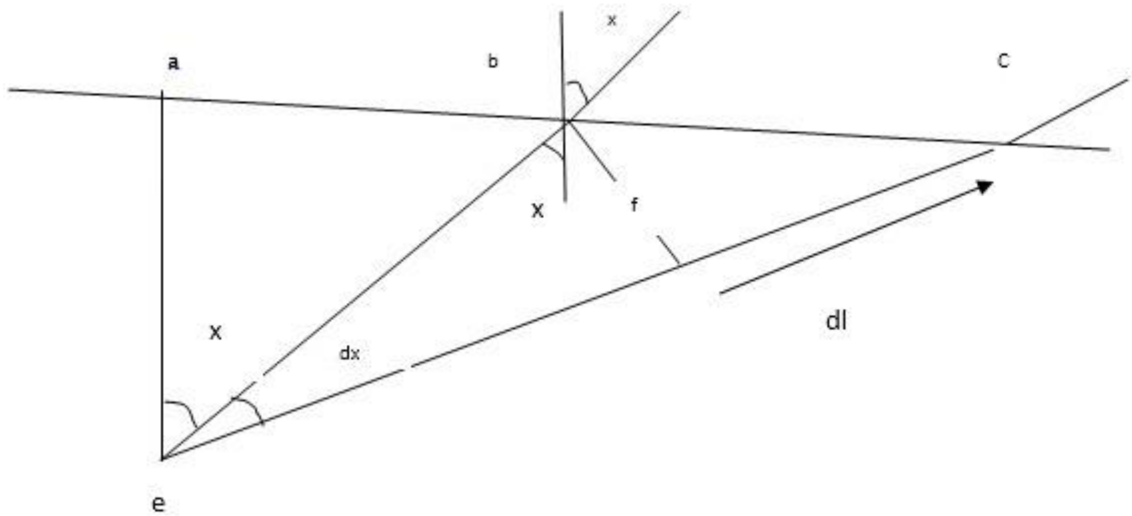
$$cb\left(1- \sin^2 x'\right) = l'\cos x'.x'd$$

$$cb\left(\cos^2 x'\right) = l'\cos x'.x'd$$

$$cb = \frac{l'}{\cos x'}.x'd = \frac{k.x'd}{\cos^2 x'}$$

Finding (be) = l

Notice the fig. (2)



$$\frac{f}{cb} = \cos x \quad , \frac{f}{l} = xd \quad \text{, then} \quad f = cb\cos x = l.xd$$

Then $\quad l = \dfrac{cb\cos x}{xd} = \dfrac{k}{\cos^2 x'}\cos x \dfrac{x'd}{xd}$

Finding (ae) = h=apparent depth

From the fig. (2)

$$\frac{ae}{l} = \cos x \Rightarrow ae = l\cos x \Rightarrow ae = k\frac{\cos^2 x}{\cos^2 x'}.\frac{xd}{x'}d$$

But

$$m\sin x = m'\sin x'$$

$$\frac{d}{xd}.m\sin x = \frac{d}{xd}.m'\sin x'$$

$$m\cos x = m'\frac{x'd}{xd}.\frac{\sin x'd}{x'd} = m'\frac{x'd}{x'd}\cos x'$$

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$$\frac{x'd}{x'd} = \frac{m}{m'} = \frac{\cos x}{\cos x'}$$

$$c = ae = \frac{m}{m'} k \frac{\cos^3 x}{\cos^3 x'}$$

$$c = \frac{m}{m'} k$$

CONCLUSION

The above derivation of equations proven that our theory coincides with the laws of the apparent and real depth theories when the angels are (x) and (x´) are of small values.

When the angles (x) and (x´) are so small we find out that this is the apparent and real depth laws where cos x = 1 and cos x´ = 1 where x = 0 and x´= 0.

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