Teacher packs in Experimental Science

PHY Pack 4

Determination of the refractive index of a liquid using the apparent depth Method

Pack contents:

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Curriculum areas covered:

Refraction, Snell's law, Real/Apparent Depth method, Geometric optics.

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Title: Determination of the refractive index of a liquid using the apparent depth Method
Target group: Diploma in Basic Education Students

Also suitable for: B.Ed Basic Education

Duration of Activity: 45mins for activity plus a minimum of 15mins for discussion

Learning outcomes:

At the end of the experiment the student should be able to

1. Knowledge and Understanding (KN)	KN1	Understand the meaning of the terms: refraction, refractive index, and parallax.
	KN2	Explain refraction in terms of Snell's law and index of refraction
	KN3	Understand the behavior of light when it travels between different media
	KN4	State refractive index in three different ways.
2. Cognitive Skills (CS)	CS1	Explain the behavior of light when it moves from one medium to another.
	CS2	Explain the concept of dimensionless parameters, and most specifically the index of refraction
3. Key Skills (KS)	KS1	Use physical laws to explain everyday physical phenomena.
	KS2	Relate dimensionless quantities to physical concepts.
	KS3	Analyze data scientifically
	KS4	calculate the refractive index of a medium.
4. Practical Skills (PS)	PS1	Measure angles accurately.
	PS2	Determine the refractive index of a given transparent glass block
	PS3	Follow the procedure to obtain values involved in the experiment.
	PS4	Set up an experiment according to verbal or written instructions.
	PS5	Make and record observations and measurements, and report results

A. Teacher's Guide

Overview

Students are required to investigate an aspect of how the eye locates images and the optical illusions that occur if light changes directions after leaving its source and passing through different media. They are asked specifically to find the refractive index of a fluid.

Aim

The students are to determine the refractive index of a liquid by the real/apparent method.

Practical Skills developed

1. Use the no-parallax technique to locate an apparent image of a real object
2. Determination of the refractive index of a fluid
3. Proper recordings of measurements, graphing and scientific analysis of graphs

Advice to Tutors

1. Encourage the students to use different depths of the liquid. They should also record their readings systematically i.e. in increasing or decreasing order of depth.
2. Create time to discuss the physics of what is going and to introduce the concepts of refractive index

Sample Assessment Questions with answers

4.1 Kofi and Ama after a physics class decided to go for a swim in a swimming pool. They noticed a coin at the bottom of the pool two meters deep. The coin appeared to be 1.4 meters from the surface of the water. What was the refractive index of water in the swimming pool? (KS4)

Answer: $$n_1 = \frac{real\ depth}{apparent\ depth} = \frac{2.0}{1.4} = 1.43$$

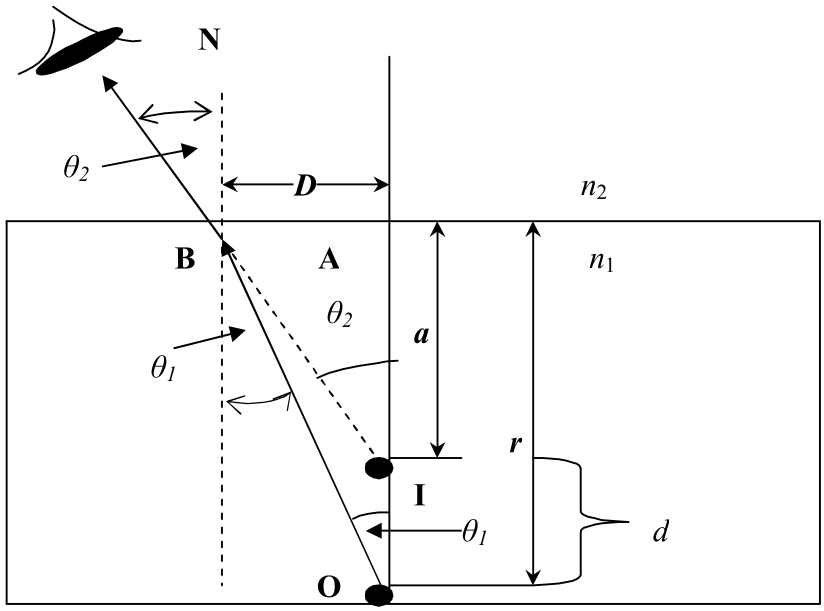
4.2 What is refraction? (KN1)

Answer: Refraction is the bending of light rays as it moves from one medium to another of different optical density.

4.3 Explain why a swimming pool appears to be shallower than it really is. (KN3)

Answer:

From the figure below, a ray of light OB from the bottom of the pool emerges into the air and it is bent away from the normal NB. The eye appears to see the image of the object along a straight line BI. The eye then sees the image I above the object. Thus, the bottom of the pool appears to be much shallower than it really is.



4.4 In what different ways can we state refractive index? (KN2)

Answer: Refractive index can be stated in terms of angles, speeds in a pair of media and depths as follows:

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1} = \frac{speed\ of\ light\ in\ medium\ 1\ (v_1)}{speed\ of\ light\ in\ medium\ 2\ (v_2)}$$

$$n = \frac{real\ depth}{apparent\ depth}$$

B. Student Guide

Purpose

To find the refractive index of a liquid using the apparent depth method

Equipment/ Materials
Retort stand (clamp and stand), tall beaker, strip of plane mirror, two optical pins, meter rule, liquid

Background to Experiment

Visible light is a small portion of the spectrum of electromagnetic radiation, which extends from low energy (very long wavelength) radio waves to high energy (short wavelength) X-rays/Gamma rays. When light rays strike the boundary between two media the rays can undergo several physical processes e.g. reflection, refraction, etc. In this experiment, we are interested in refraction. We can define refraction as "the bending of light rays as they move from one medium to another of different optical density". We now know that light bends but in which direction does it bend? Is it away from the normal to the boundary or towards the normal? One physical parameter which can give a measure or degree of the bending after refraction is the index of refraction or simply, the refractive index.

Index of Refraction
The refractive index is a dimensionless parameter that helps us in our estimation or determination of the degree of bending for a ray of light entering one medium from another. The refractive index *n* can also be defined for a particular material as the ratio of the speed of light in vacuum or free space to the velocity of light through the material (See Equation 1.1).

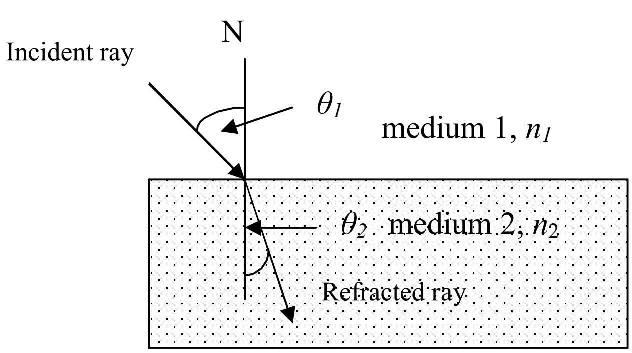


Figure 4.1 Refraction of light at the boundary between two media

The refractive index also depends on the wavelength (colour) of the light ray. Note that standard values of refractive indices given for materials or substances apply to yellow light of wavelength 589nm (1nm=1 nano meter = $1\times10^{-9}\,m$).

Generally, Snell's law for light travelling from medium 1 to medium 2 (Refer to Figure 1.1) can be written as:

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1} = \frac{speed\ of\ light\ in\ medium\ 1\,(v_1)}{speed\ of\ light\ in\ medium\ 2\,(v_2)} \qquad 1.1$$

Apparent Depth

An object at the bottom of a swimming pool or a clear lake appears to be closer to the surface than it actually is. This phenomenon may be understood by examining the light rays which pass from the object to the eye.

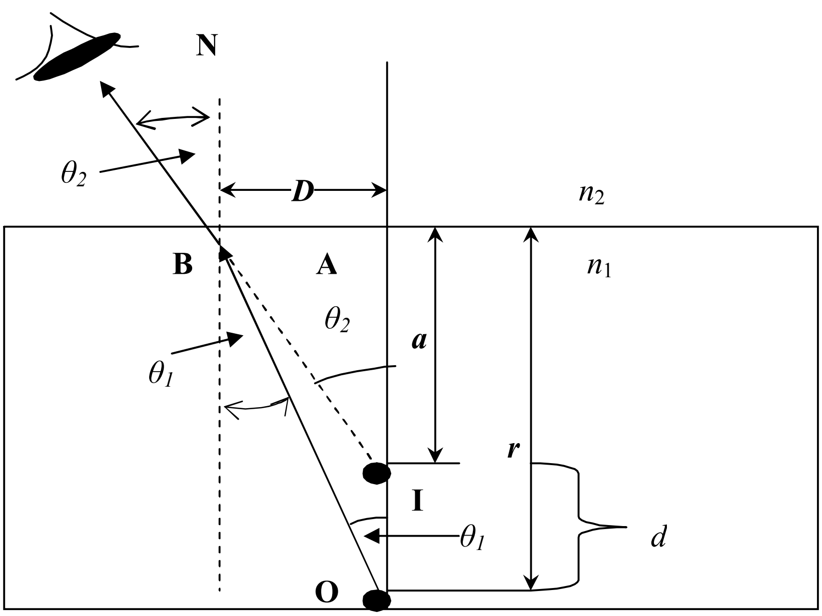


Figure 4.2 Relation between real depth and apparent depth

Refraction causes an object immersed in a liquid of higher refractive index to appear closer to the surface than it actually is. This shallowing effect is illustrated in Figure 1.2. This is because the light from the point O that enters the eye is bent away from the normal as it emerges from the surface at point *B*. So the observer sees this ray appearing to come from the direction of *B* projected backwards into the water, along the dotted line, and so it seems to have come from the point *I*. The apparent depth is denoted by *a* and the real depth by *r*. Snell's law applied at the surface gives

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1} \qquad 1.2$$

$$\frac{apparent\ depth}{real\ depth} = \frac{a}{r} = \frac{IA}{OA} = \frac{n_2}{n_1} \qquad 1.3$$

If medium 2 is air ($n_2 \approx 1$), then we write

$$\frac{apparent\ depth}{real\ depth} = \frac{a}{r} = \frac{IA}{OA} = \frac{1}{n_1} \qquad 1.4$$

from which we can find the refractive index of the medium in which the ray originates, n_1, by rearranging to give:

$$n_1 = \frac{real\ depth}{apparent\ depth} = \frac{r}{a} \qquad 1.5$$

This implies the refractive index of a medium in air is equal to the ratio of the real depth to the apparent depth.

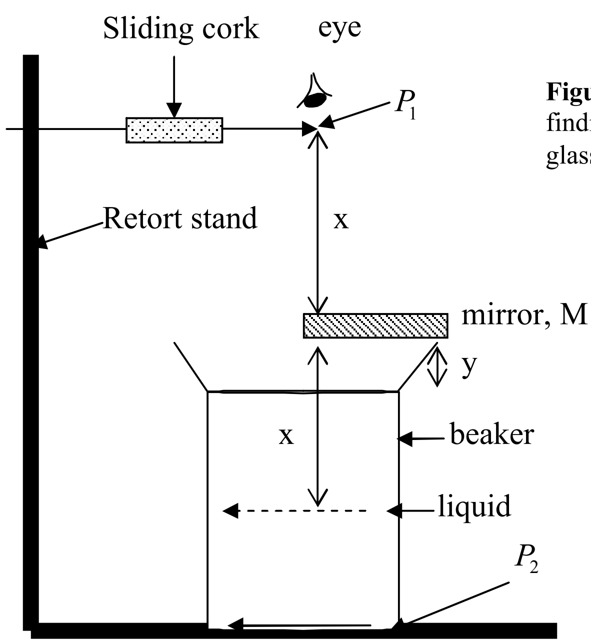


Figure 4.3. Experimental setup for finding the refractive index of a glass block.

Experimental Procedure

1. Place a tall beaker containing a given liquid, on the base of the stand. Measure the depth of the liquid and record its value as D (draw D in diagram).
2. Place an optical pin P_2, at the bottom of the beaker and another pin, P_1, held in a sliding cork above the liquid in the beaker, in a clamp.
3. Place a strip of plane mirror across the mouth of the beaker so that it covers about half of it.
4. View the pin, P_1, with the eye above it and adjust its position by raising it up or down until its image as seen reflected from the mirror, coincides with the image of the pin P_2, as refracted by the liquid.
5. Measure the distance between P_1 and M and record it as x. Measure also the distance between M and the liquid surface and record the value as y.
6. Determine the apparent depth as (x-y)

7. Repeat the steps 1-6 four times by varying the depth of liquid (preferably increasing it) and adjusting the position of P_1 for no parallax.
8. Tabulate your readings for the real depth D and apparent depth (x-y) and plot a straight graph with D as the ordinate and (x-y) as the abscissa.
9. Determine the slope.
10. What does the slope represent?

Tabulate your results as shown below

Experiments	D/cm	x/cm	y/cm	(x-y)/cm
1	…..	…..	…..	…..
2				
3				
4				
5				

Reflection on the experiment

1. What is meant by no parallax?
2. State two precautions taken to obtain accurate results.

C. Assessment – Student's sheet

On completion of the experiment, you should answer the following questions:

1. After a Physics class, Kofi and Ama decided to go for a swim. They noticed a coin at the bottom of the swimming pool. The pool was two metres deep but the coin appeared to be 1.4 metres from the surface of the water. What was the refractive index of water in the swimming pool? (KS4)

2. What is refraction? (KN1)

3. Explain why a swimming pool appears to be shallower than it really is. (KN3)

4. In what different ways can refractive index be stated? (KN2)

D. Extensions to experiment

a. Perform the same experiment using kerosene as a liquid
b. In place of the transparent fluid, use a transparent rectangular glass block.

E. References and Other Useful Links

1. Abbot A. F. (1980), *Ordinary Level Physics*, 3rd Edition, Heinemann Books International, London.

2. Moss G. L. (1963), *Ordinary Level Practical Physics*, Heinemann Books International, London.

3. Nelkon M. and Parker P., (1987), *Advanced Level Physics*, Heinemann Educational Publishers, London.

F. Health and Safety

1. Care should be taken to avoid breaking the mirror and the beaker
2. If you use a liquid other than water make sure that you wash your hands with soap and water immediately afterwards, and before handling any food or drink.

G. Evaluation