The Magic of Refractive Index

How are we able to see transparent objects? They are distinguishable because when light passes from one medium to another of a different refractive index, light is reflected at the boundary. The behaviour of light at the boundary is described by Fresnel's equations. Though the term is not widely used in school physics, the reflection is called Fresnel reflection. Glass has a refractive index of around 1.4, whereas air has a refractive index of 1.0, so glass objects are easily seen.

If a transparent object is immersed in a transparent liquid that has the same refractive index as the material the object is made of, it disappears. This striking demonstration is easily performed. A Pyrex test tube is immersed in glycerol (Fig 1). Pupils will be amazed to see the small test tube suddenly appear when some of the glycerol is poured away (Fig 2).

Figure 1: A small test tube almost invisible inside a larger tube of glycerol

Figure 2: The small Pyrex test tube only becomes visible when some of the glycerol is poured away

If a plastic convex lens, the type used for ray tracing, is immersed in light oil [1] the lens is immersed in a liquid with the same refractive index as the plastic it is made from and the lens does not focus the light, (Fig 3), as it does if it is in air (Fig 4).

This happens because there is no refraction of light at the oil/plastic boundary as there is no change in the speed of the light as it passes from one medium to the other because they both have the same refractive index.

On looking more closely at the behaviour of the lens in air and in glass it is clear there are no Fresnel reflections when the lens is immersed in a liquid with a matching refractive index.

Index matching fluids are used when coupling light into optical fibres to reduce losses. Forensic scientists can identify whether the glass at the scene of a crime matches that found on a suspect by looking at the two samples of glass in oils of different refractions to see if they both disappear in the same oil and are therefore identical types of glass [2]. The concentration of sugar in water can be calculated by measuring the refractive index of the sugar solution. Biologists use immersion oil when doing high resolution microscopy to produce a high quality image [3], as the matching fluid prevents any refraction and Fresnel reflection occurring. These would lead to degradation in the quality of the image. Chemists use solvents to distinguish between soda and pyrex glass. This is described in SSERC Bulletin 182 [4].

The experiments shown here could be used to enhance or challenge a student's understanding of refraction or could be developed into a project for Advanced Higher Physics.

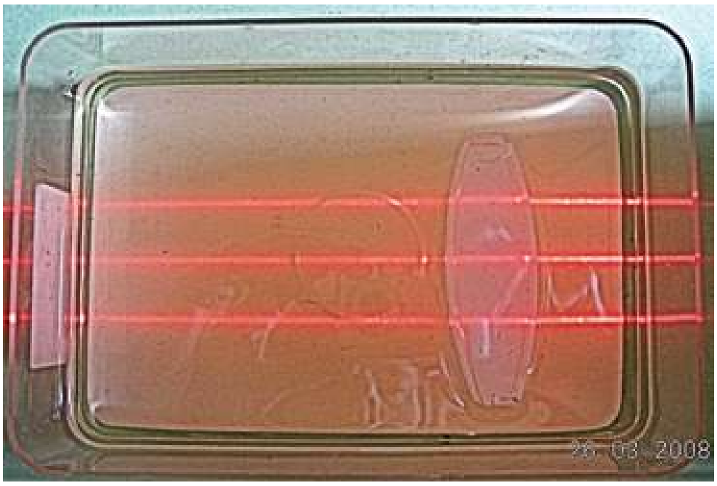

Fig 3: Convex lens in light oil

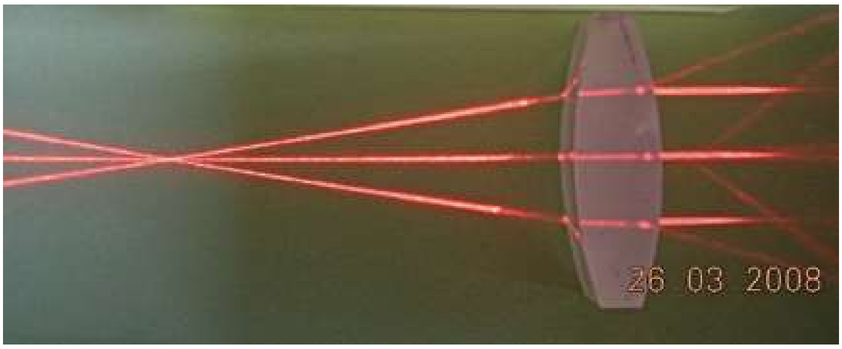

Fig 4: Convex lens in air

References

1 The supermarket Morrison's own brand of Light Cooking Oil worked well.

2 http://www.ncsu.edu/kenanfellows/2002/pligon/forensics/labs/GlassLab.html

3 http://biology.clc.uc.edu/fankhauser/Labs/Microscope/Oil_Immersion.htm

4 Distinguishing Glass Types, SSERC Bulletin 182, P40, 1994