Practitioner Journal of Mathematics and Science Teachers, (PJM&ST)
Volume 1 Issue 1, pp 17-19

Demonstrating the Critical Angle and Total Internal Reflection Using a Laser Beam

John Kiplimo Chumo

Abstract

This article demonstrates my experience as a Physics teacher and the challenges I faced when guiding learners to experiment to understand what a critical angle is, and the conditions necessary for total internal reflection to occur. In the article, I have also shared how I overcame these challenges by designing an *Optical Model*. Further, I have also shared the benefits of the model against the existing and recommended apparatuses as listed curriculum materials that include the syllabus and textbooks. Given its advantages in aiding learning, I strongly recommend its use in teaching the content on a critical angle and total internal reflection in physics.

Keywords

Critical angle, Laser beam, Optical model, Refraction, Total internal reflection

Introduction

Critical Angle and Total Internal Reflection are concepts taught in Form Three in the Kenya Secondary School curriculum under a topic called Refraction of Light (Kenya Literature Bureau, 2017). The concepts are necessary for explaining how devices such as prism binocular, pentaprism and optical fibres work. Sometimes, learners find it challenging to understand why and how light can be refracted and reflected internally by a material when the critical angle is exceeded. This problem is compounded by the nature of the learning materials recommended in the syllabus and textbooks. The materials provide the guideline of using optical pins and a ray box. However, the two options provided by the syllabus have weaknesses. For example, while using the optical pins, a learner is required to hold the glass block closer to one eye. Unfortunately, learners suffering from long-sightedness will not make any observation of the pins' images. The ray box, on the other hand, produces scattered rays of light which makes it hard to trace the path travelled by the refracted ray. Additionally, using a ray box requires that the experiment is done in a dark room; obtaining this during the daytime is challenging in a normal school laboratory. Handling learners in a dark room compromises their safety too. In this article, I describe how I overcame these challenges by designing a teaching model called the *Optical Model*.

Teaching the Content on Critical Angle and Total Internal reflection

One day, I was guiding learners in the laboratory to experiment to demonstrate what a critical angle "C" is and the conditions necessary for the occurrence of total internal reflection. In optics (which is a branch of Physics) a critical angle is the angle of incidence in an optically dense material (for example glass) whose angle of refraction in an optically less dense material (for example air) is 90^0.

Initially, I used four optical pins and a semi-circular glass block. However, some learners who were long-sighted could not trace the images of the optical pins. This is because, for one to view the images of the optical pins, one has to hold the semi-circular glass block closer to the eyes. Questions from students such as "what am I supposed to see? or statements such as "I cannot see anything" indicated that the apparatus used did not favour all learners since the desired outcome was not achieved. As a concerned teacher, I resorted to another alternative, I replaced the optical pins with a Ray Box. Unfortunately, the ray box failed because it produced a divergent beam of light that could not be focused on a screen to show total internal reflection.

To address this challenge, I designed an *Optical Model*. This is bearing in mind that applications of teaching models in physics reinforce learners' understanding of scientific concepts. Further, the teaching models are crucial in clearing up misconceptions and increasing learners' ability to apply concepts in real-life situations (Archer & Ng, 2016; Shahan & Jenkinson, 2016). In addition, the learning models in physics can be used to demonstrate the link between theory and practice (Korsun, 2017). Figure 1 is a diagrammatic representation of the Optical Model which I designed to enhance the understanding of the two concepts.

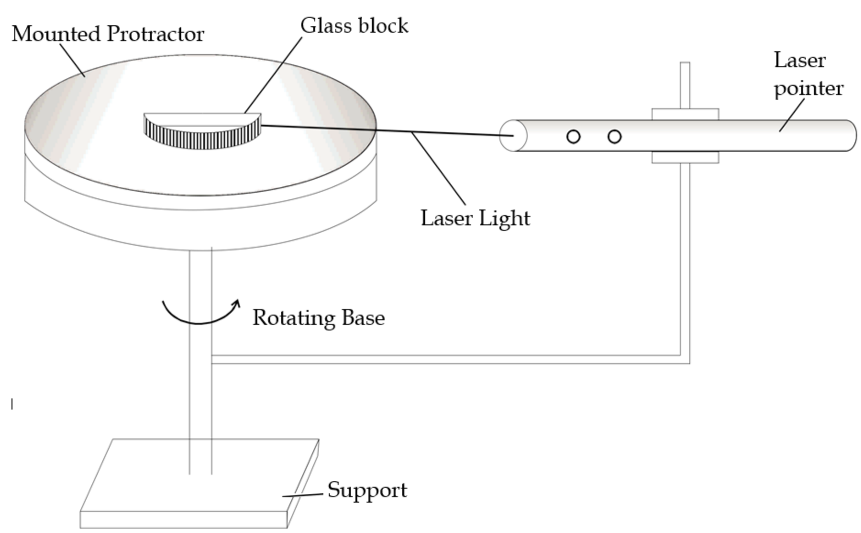

Figure 1: Optical Model

The model is fitted with a semi-circular glass block and protractor where both are mounted on a rotating base. Further, a fixed laser pointer is attached to the model as a source of light.

How the Optical Model Works

The incident light from the laser pointer is cast on the curved side of the semi-circular glass block such that the laser light goes through the normal (an imaginary line that is perpendicular to the glass surface). The rotating base is slowly rotated so that the angle of incidence is slowly increased from 0^{o}. The rotation of the base is done until the angle of refraction in the air is 90^{o}. At this point, the critical angle, C, is obtained. When the critical angle is exceeded by rotating the base further, the light is fully reflected by the glass block. As such, the phenomenon of total internal reflection is easily observed. To understand more how the Optical Model works, watch a short video clip available at https://youtu.be/k6Wo_uWMeeM.

Benefits of using *Optical Model* over the Optical Pins and a Ray Box

The following are the benefits of using the Optical Model over optical pins and the Ray box.

- *The Optical Model* uses laser light which is focused (non-scattered). As a result, it clearly shows the path of light as it moves from glass to air; showing clearly the critical angle 'C' in a glass when the angle of refraction in the air is 90^{0}.
- When the critical angle is exceeded, the reflected light (as a result of total internal reflection) is visible on the screen mounted on the model.
- The protractor which is also mounted on the model makes it easy to measure the angle of incidence and angle of reflection of light in glass.

- Further, since the laser light is coloured (red or blue), the model makes it possible to experiment without the need of creating a darkroom in the laboratory.
- In addition, as opposed to the use of optical pins which must be held close to the eyes, learners who are long-sighted can easily make observations using the *Optical Model.*
- Additionally, the *Optical Model* is a unit system and light. This makes it easy to use and carry around.

Conclusion

The beauty of learning physics lies in its ability to explain complex ideas in the simplest ways. In this article, I have described how this can be achieved by using the Optical Model in Refraction. By using the Optical Model, learners will have an opportunity to see, touch, and feel what they are learning by interacting with this model. On the other hand, the model simplifies the work of the teacher. This is because learners' involvement in the learning process is enhanced by interacting with the model. As such, I highly recommend its application as a way of simplifying the understanding of what a critical angle is, and the conditions necessary for total internal reflection to occur.

References

Archer, L. A. C., & Ng, K. E. (2016). Using the scientific method to engage mathematical modelling: An investigation of pi. *Journal of Education in Science, Environment and Health*, *2*(1), 51-56.

Kenya Literature Bureau (2017). *Secondary Physics Students' Book Three*. Kenya Literature Bureau. Nairobi.

KNEC [Kenya National Examination Council] (2018). Kenya national examination council report 2018. Nairobi: Kenya National Examination Council.

Korsun, I. (2017). The use of the interdisciplinary approach for the formation of learners' situational interest in Physics. *Asia-Pacific Forum on Science Learning and Teaching*, 18 (2), 1-15.

Shahan, V. M., & Jenkinson, J. (2016). The efficacy of interactive analogical models in the instruction of bond energy curves in undergraduate chemistry. *Chemistry Education Research and Practice*, *17*(2), 417-428.

Author Information

John Kiplimo Chumo
Chebara Girls Secondary School-Marakwet
P. O. Box 7755 – 30100
Eldoret, Kenya
Email: johniechumo@gmail.com