行政院國家科學委員會補助專題研究計畫成果報告

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※ **中學物理網路課程之發展與研究(II)** ※
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執行期間：89 **年** 8 **月** 1 **日至** 90 **年** 7 **月** 31 **日**

計畫主持人：錢正之

執行單位：淡江大學教育科技學系

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行政院國家科學委員會專題研究計畫成果報告

中學物理網路課程之發展與研究(II)

Development and Research on Web-based High School Physics Courses (II)

計畫編號：NSC 89 - 2511 - S - 032 - 008

執行期限：89 年 8 月 1 日至 90 年 7 月 31 日

主持人：錢正之　淡江大學教育科技學系

Abstract

In the course of refraction, the law of refraction is introduced to help students determine how the refracted light bends. In fact, the law of refraction is a consequence of the fact that "light travels with different speeds in different media," rather than the cause of refraction. In this computer-based module, students first study the tank analogy on how the speed and direction would change at the interface when the tank travels from a hard surface to sandy surface. When students realize how different travel speeds would determine the direction of refracted light, they don't need to memorize the above rule. Then many phenomena related to refraction such as lenses, rainbow, mirage, and total reflection can be easily explained qualitatively to students. The material discussing relation between the tank analogy and the mathematical derivation of the Snail's law is provided as a reference for college students and high school teachers.

Introduction

In our everyday experiences, many familiar phenomena such as rainbow and magnifying lens are caused by or designed with the law of refraction. When learning refraction in our physics courses, students learn many equations such as the law of refraction $n_1 \sin\theta_1 = n_2 \sin\theta_2$, or the lens maker's equation $\frac{1}{f} = (n-1)(\frac{1}{r_1} - \frac{1}{r_2})$ to calculate the path of the light beams. When we ask students what causes mirage and rainbow, or why you miss the fish if you point directly to the fish in the river, their answer is "refraction." However, if you further ask them: Can you use the principles learned in refraction to explain these phenomena? They might tell you those equations are not used for explaining these phenomena, but for calculating certain types of problems as provided at the end of the textbook. Is it true that mathematical formulas are used for calculation only, and not useful for describing the phenomena without numbers? The answer is "no" for physicists. The question is: How do we help students realize that these mathematical formulas are also powerful qualitative tools for analyzing and describing our everyday experiences? This is the purpose of this web-based refraction learning module.

Law of Refraction Revisited

The law of refraction (or Snell's Law) describes how the light beam refracts when passing the interface of different materials. In the introductory physics textbook (Halliday, Resnick, and Walker, 1997), the Snell' s law is derived from the Huygens' Principle. Many students regard this part as algebraic exercise, and the final equation is the only useful product from this process. With the Snell's law, students memorize the rule of the refraction: When the light travels from a low refraction index medium to a high index medium, the light bends toward the normal line; when the light travel from the high index medium to low index medium, the light bends away from the normal line. During the class, students try to memorize the rule. When the course is over, this rule becomes very confusing. The reason why this rule is difficult to remember is because this rule is not meaningful for students. Memorizing the rules does not give students a meaningful way to help them determine the direction. Thus students have to memorize the two very similar cases.

In fact, this derivation explains why the light beam refracts when passing the interface of two different media. When a wave front partly goes from the air into the water, the half in the air travels faster than the half in the water (see Figure 1). Also, the relation of light speed and wavelength is c = λ/ν. Through the above information, the relation of angle of incidence and the angle of refraction can be derived as $n_1 \sin\theta_1 = n_2 \sin\theta_2$.

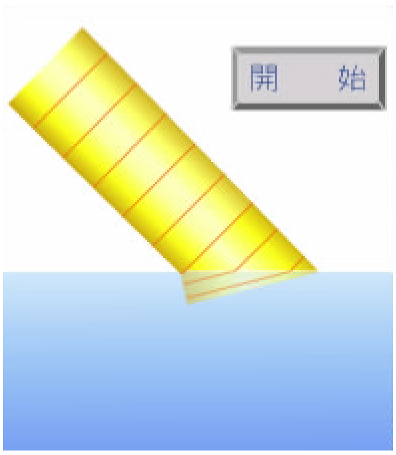

Figure 1. Light beam incidents from one medium to another with different refraction indices. Different light speeds in the same light beam causes the light bends toward the slower side.

The above mathematical derivation can be restated in our daily language:

Due to the different speeds in different media, one half of the wavefront moves relatively faster and the other half moves slower. Therefore, the light must bend in a certain way.

This is the fundamental reason of refraction phenomena. In the next section, this process is used to help students determine the direction of refraction through reasoning. This same strategy is also used to explain some familiar phenomena such as rainbow and mirage.

Activity Design

The learning activities are designed based on the Chain Model for technology-based instructional design (Chien, 1998). This model is more appropriately considered as a thinking process based on the content nature to design technology-based materials, rather than a model for instructional designers to fill different types of activities at various stages. Four fundamental questions are to be addressed in this model. First, what are the special features of the topic and the accompanying learning problems in the content area? Second, what are the appropriate learning strategies that can be used to help students solve these problems? Third, how technologies can be used to illustrate the contents? Finally, how technologies are engaged in the learning activities to facilitate the selected learning strategies?

In this model, the first question is to consider the special features of the topic and the associated student learning problems. As well known by science educators, students who are capable of applying mathematical equations to solve numerical problems might not be able to use the same tool to reason about real life phenomena. In most exercises on refraction, students apply Snell's law or other principle to calculate problems about angles. However, when asked about the cause of rainbow or mirage, they would think these principles are not for this type of questions. Is it true that the Snell's Law is not useful in describing and explaining refraction phenomena qualitatively?

The second question in the Chain Model is what strategies can be adopted in the learning activities to help students overcome the above learning problems. To help students understand the relationship between the refraction principle and the real life phenomena, it is important to ensure students realize the meaning of this principle and learn to use it as an analyzing tool. From the constructivist perspective, it is important for students to go through the same analyzing process and try to use the fundamental knowledge learned in class to predict and evaluate the explanation.

So far the technology has not been discussed yet in the first two questions in the Chain Model. However, the content and strategy needs are the main factors to determine how technologies should be used in the learning activity design. The third question is how technology can be used to better illustrate the content. In this refraction module, a tank is used as an analogy to illustrate how different speeds of light beams causes the refraction (see Figure 2). A motion picture illustrating the effect of wheels at different sides running at different speeds is used as an analogy to help students visualize the effect of different speeds in a light beam.

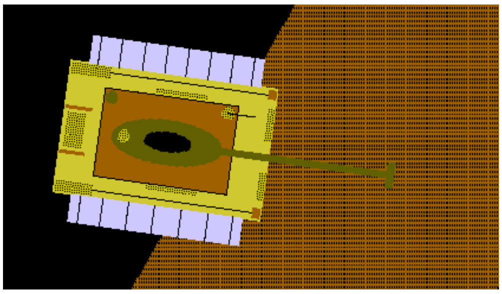

Figure 2. Using a tank as an analogy to illustrate the refraction caused by different speeds.

For the fourth question, the computer simulations allow students to change the wavelength and media (index of refraction). Students do not just type in different numbers to see different motions. This part of activities asks them to predict the results and explain their reasons before running the simulations. The purpose of the activities is to guide students to evaluate their knowledge and reconcile the differences. Through the process of predicting, explaining, and revising (when needed), students can better construct their knowledge framework of refraction.

This module is composed of four sections. The first section introduces students how to use the fact that light travels in different speeds in different media to determine the direction of refraction beam. The second section discusses how the image is formed in our eyes. The third section and forth section use the skills leaned in the previous two sections to analyze different phenomena with different wavelength and different media.

The introduction section uses a car analogy to help students determine the direction of refraction beam. In this section, students are asked to imagine a car's motion. "Consider you are driving a car or playing with a toy car. For some reason if the left wheels move faster than the right wheels, in what direction the car would turn?" Most students can easily determine that the car is turning right when left wheels move faster than the right wheels. In a similar case, when moving from the highway to the sand beach, the tank would become slower. When a tank moves from the highway to the beach with a non-perpendicular angle (as in Figure 2), the tank would turn to the side where the wheels travel slower.

This simple fact, in fact, is the basic idea of the derivation of Snell's law from the Huygens' Principle. Because one half of the wavefront moves faster and the other half moves slower, the light beam must turn toward the slower side. After realizing why the light would turn, students are given different cases to apply this rule. In the following exercises, students are given sand areas with different shapes and asked to apply the above rule to determine how the tank would turn when passing these areas. These shapes represent the prism and concave lens and the paths of the tank represent how the light would bend when passing these optical instruments.

The first section discusses why light beams bend when passing different media. The second section explores how refraction affects the images we see. The process of visualization is illustrated with animations by the following three steps: 1) light beam from light source to the object, 2) from the object to our eyes, and 3) image formation by our eyes. The third step usually needs more explanations to students. Because our eyes are used to judge an object's size and location in the air (without other media such as water or glass in between), the virtual image we see is located traced back from the light path (see Figure 3). At the end of this section, a few exercises are given to analyze a few familiar phenomena such as why we see through a concave lens would see a larger image (in a certain range) and what happens when seeing a coin in the bowl with water.

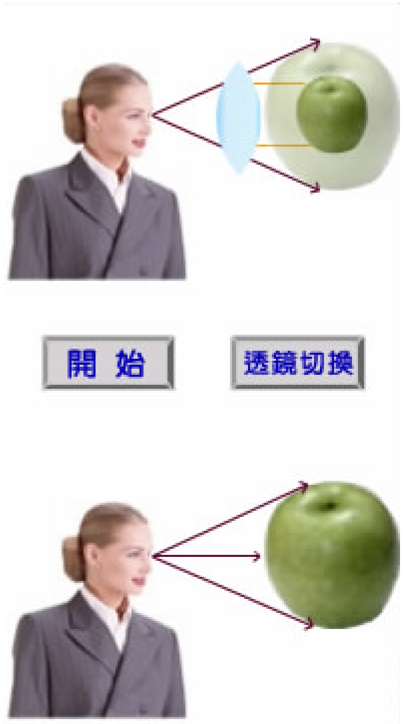

Figure 3. Animations showing the dynamic process of light beam from light source to the object, object to our eyes, and image formation.

In the first two sections, students learn how the light bends when passing different media and how the bending light affects the image we see. In the following sections, we analyze the media (index of refraction) and the wavelength to study how the light beams bend and how they affect image we see. One example is the mirage. Considering the road is heated by the sun, the air near the surface is hotter than the air. In this problem, first we ask students to use the tank analogy to analyze to which direction a light beam would bend, and draw a possible path of the light beam linking the real object and our eyes. Second, students draw a straight line from our eyes parallel to the final part of the light path. Along this straight line is the image we see. This same strategy is used to analyze total refraction and rainbow.

Discussion

The module emphasizes the qualitative reasoning of refraction phenomena. Through this example, many fundamental principles and equations can be used for reasoning purposes, rather than just a calculation tool. When discussing about qualitative understanding, many people regard it as "facts without equations". And equations' purpose is for quantitative use only. However, if we carefully study the meaning of the mathematical principles, they can be very powerful tools in daily reasoning without the presentation of numbers.

Reference

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