An activity sheet for teaching double-slit interference

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An activity sheet for teaching double-slit interference

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Abstract. This study aimed to enhance students’ understanding in double-slit interference; especially the optical path difference. An alternative teaching tool called ‘Activity Sheet’ was developed and applied to the introductory physics class at Mahidol University in academic year 2016. The activity sheet contains a diagram of the double slit with two transparent strips. The sinusoidal wave pattern together with a ray of light printed on the strip was used to represent the light wave coming out of the source. Each strip is pinned at the point source and can be rotated around the pinned point. The results from the test indicate that most students realized the importance of the path difference after they had learnt with the activity sheet. In addition, most students from the interview said that learning with activity sheet helped them understand double-slit interference better and made it easier to visualize the superposition of interfering light waves.

1. Introduction

Interference of light is one of the most important topics in wave optics. The concept of interference can be used to describe the bright and dark fringes on the screen when the light waves passed through a double-slit. However, teaching students to understand the principle of interference is quite difficult because we cannot visualize the light waves directly with naked eyes. The results from the previous research [1] indicated that many students who have studied the introductory calculus-based physics course did not recognize that the key concept of double-slit interference was the optical path difference (OPD). It motivated us to create an instructional tool that help students realize the concept of the path difference in double-slit interference and visualize light wave more easily.

2. Methodology

Data were obtained from 226 first-year science students enrolled in the Introductory Physics course at Mahidol University in academic year 2016. In the course, there were two lectures per week, each lecture lasted for one and a half hour. Supportive team teaching was applied in all the lectures by two lecturers [2] (see figure 1).

In the year 2016, an ‘Activity Sheet’ has been developed and added during the instruction about the optical path difference in double-slit interference. The activity sheet is different from the general worksheet that it adds a simple demonstration kit into the worksheet. In addition to taking notes on the worksheet and seeing demonstrations performed by the lecturers in front of the classroom, the students had to practice with the activity sheet by themselves. During learning, the students were asked to operate the activity sheet in pairs (see figure 2). The detail about the activity sheet and how to use it...
will be explained in the next section. In addition to the activity sheet, the general worksheet was also given to each student. It was used to teach the derivation of the formula $d \sin \theta = m \lambda$ and how to use it to solve the problem. The teaching with activity sheet and this worksheet covered about 2 lectures.

Figure 1. The Introductory Physics course at Mahidol University in academic year 2016.

Figure 2. A pair of student learning with the activity sheet.

The pre-test and post-test (adapted from [1]) were used to assess students’ understanding about the optical path difference and the formula $d \sin \theta = m \lambda$ in double-slit interference. The students were asked to complete the pre-test before lecturing about double-slit interference. The post-test was collected one week after the instruction. Two weeks after the instruction, 20 out of all students were interviewed about their satisfaction with the activity sheet.

3. Design of Activity Sheet
In standardized textbook [3], there are two main approaches to visualize light waves in double-slit interference; the first one is the use of a diagram of wave fronts coming out of the two sources, and the second approach is by using rays of light with sinusoidal curves. Previous research on physics education indicated that increasing student engagement in classroom by using a demonstration kit could help improve students’ learning [4] as well as help them visualize physics phenomena more easily. One of the most widely used instruction media for teaching how the interference occurs is the circular wave fronts printed on the transparent sheets [5]. However, the idea of using sinusoidal curves to represent light waves is another interesting method which may help students visualize the results of the superposition of waves [6]. The sinusoidal curves combined with the use of transparent sheets were then used to represent light waves in this research.

3.1. Overview of the Activity Sheet
The activity sheet contains a diagram of the double slit with two transparent strips (see figure 3). The sinusoidal wave pattern is printed on the transparent strip. The wave on each strip has the same wavelength ($\lambda = 1.4$ cm). The middle line on the strip represents the ray of light wave. There are small dots on the middle line where the wave phase is 90 degrees. Each strip is pinned at each point source (S1 and S2). One strip represents one wave coming out of the source. To make it easy to refer to which wave coming from S1 or S2 during the lecture, the colour of the waves on the strips were made different (blue and red). The strip can be rotated around the pinned point. At the pinned points, the two waves have the same phase, which is 90 degrees. Therefore, the two sources are said to be coherent. In addition to the double-slit diagram with the transparent strip, the activity sheet also contains empty boxes for students taking notes during the lecture. The boxes help students summarize the optical path difference concept obtained from the use of the diagram together with the strips.

3.2. Teaching Procedure with the Activity Sheet
3.2.1. Step 1: Using the transparent strips to solve whether at each determined point (a-f) the interference is constructive or destructive. The phase of waves from S₁ and S₂ at points a, b, c, d, e and f are set to 90-90, 180-180, 270-270, 0-0, 45-45, and 180-0 degrees, respectively. To answer this question, the students could rotate the two strips to each point until their middle lines intersect at that point. Students could then determine the phase of the waves from the two sources at that point and then calculate the phase difference.

3.2.2. Step 2: Drawing a line to create a screen and finding the points where the constructive interference occurred on the screen. To solve this problem, the students had to rotate the two strips to find the points on the screen where the phase difference of the two waves is zero. For this set up, there are two positions on the screen (above the middle horizontal dashed line) that the waves from the two sources are in phase; the first constructive interference occurred when the phases of the two waves are zero, and the second constructive interference happened when the phases of the two waves are 90 degrees.

3.2.3. Step 3: Determining the difference of the path length of the two wave paths (in term of $\lambda$) at the first and second constructive interference on the screen. The path length from the sources S₁ and S₂ to the first constructive interference are 6.75$\lambda$ and 7.75$\lambda$, respectively, and those to the second constructive interference are 7$\lambda$ and 9$\lambda$, respectively. Therefore, the optical path differences at the first and second constructive interference are then $\lambda$ and 2$\lambda$, respectively. Hence, the process...
reveals that the constructive interference occurs when the OPD is equal to the whole number of the wavelength, i.e., \( \text{OPD} = m\lambda \) (where \( m = 0, 1, 2, 3, ... \)).

3.2.4. Step 4: Finding the type of interference at point ‘g’ without using the transparent strips. The students had to use the ruler to measure the distances from \( S_1 \) and \( S_2 \) to point ‘g’ which is about 11.6 cm and 9.5 cm, respectively. The optical path difference is then 2.1 cm. The students could then convert this into the OPD in term of wavelength which is 1.5\( \lambda \). Therefore, the destructive interference occurs at point ‘g’.

4. Results and Discussions
The results from the test show that most students used the concept of the optical path difference to solve the problems after the instruction. Some students used the formula \( d \sin \theta = m\lambda \) which is an alternative way to find the answer. Student’ responses to the interview were analyzed in terms of positive or negative comments on learning with the activity sheet [7]. The results showed that 19 out of 20 students provided positive feedback to the activity sheet. It was also found that there are 13 out of 20 students who talked about ‘visualizing’ during the interview. They said “The activity sheet made it easier to visualize where the constructive and destructive interference occur”. Moreover, 5 students stated that the activity sheet allowed them to practice on their own. This means studying with activity sheet supports active learning.

5. Conclusions
This study proposes an activity sheet to help students understand double-slit interference. It was found that the activity sheet could be used to enhance student recognition about the use of the optical path difference rather than using the formula \( d \sin \theta = m\lambda \) during solving the problem. In addition, student interview also showed that most students gave positive responses to the activity sheet. They reasoned that it could help them visualize light wave more easily.

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References
[1] Ambrose B, Shaffer P, Steinberg R and McDermott L 1999 An investigation of student understanding of single-slit diffraction and double-slit interference Am. J. Phys. 67(2) 146
[2] Wutchana U and Emarat N 2011 Student effort expectations and their learning in first-year introductory physics: A case study in Thailand Phys. Rev. St Phys. Educ. 7(1) 010111
[3] Young H, Freedman R and Ford A 2008 Sears and Zemansky's University Physics vol 1 (San Francisco, CA: Pearson Education) p 1164
[4] Crouch C, Fagen A, Callan J and Mazur E 2004 Classroom demonstrations: Learning tools or entertainment? Am. J. Phys. 72(6) 835
[5] Goto H 2009 Moiré patterns allow us to visualize the interference between propagating waves Phys. Educ. 44(4) 338
[6] Mešić V, Hajder E, Neumann K and Erceg N 2016 Comparing different approaches to visualizing light waves: An experimental study on teaching wave optics Phys. Rev. St Phys. Educ. 12(1) 010135
[7] Sujarittham T, Emarat N, Arayathanitkul K, Sharma M, Johnston I and Tanamatasayarat J 2016 Developing specialized guided worksheets for active learning in physics lectures Eur. J. Phys. 37(2) 025701