Targeted Learning Intervention Report: Thin Film Interference

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Introduction

Thin film interference is a visually striking and conceptually rich topic in the Malaysian Matriculation Physics syllabus. It explains phenomena such as the colorful patterns in soap bubbles or oil films, and underpins technologies in anti-reflective and high-reflective coatings. The topic involves principles of wave optics, particularly interference due to path difference and phase changes upon reflection. Mastery of this topic is critical not only for exams but also for appreciating optical engineering applications.

Background and Rationale

Five students, aged 18 to 19, were selected for this intervention based on diagnostic quizzes that revealed weak understanding of phase changes during reflection, incorrect identification of constructive and destructive interference conditions, and inability to relate thickness of films to interference outcomes. Interviews and written responses suggested that students were memorizing formulas without grasping the underlying wave behavior. The intervention aimed to correct these misconceptions using visual reasoning and structured worksheets.

Theoretical Framework

This intervention is grounded in constructivist learning theory, particularly the idea that conceptual change arises when learners confront cognitive dissonance between prior misconceptions and observable evidence. In the context of wave optics, students often hold naïve or incomplete models of light behavior, particularly regarding phase changes upon reflection and interference outcomes.

The pedagogical approach aligns with Piaget's model of assimilation and accommodation, where students reorganize their cognitive frameworks through guided questioning and diagrammatic reasoning. The use of visual tasks and annotated ray diagrams encourages dual coding, as posited by Paivio, which facilitates deeper integration of verbal and visual information.

Cognitive Load Theory also informed the intervention design. Tasks were sequenced to minimize extraneous cognitive load by breaking down abstract concepts into manageable steps, such as identifying phase changes, sketching ray paths, and applying interference conditions in isolation before integrating them. Peer discussion was used to support Vygotsky's Zone of Proximal Development, providing scaffolding through social interaction and prompting articulation of reasoning.

By combining guided inquiry, peer collaboration, and low-tech visualization, the intervention supports meaningful learning while addressing common misconceptions in thin film interference.

Methodology

The intervention was conducted over two 45-minute sessions using only pen, paper, and a printed worksheet. In Session 1, students reviewed the conditions for constructive and destructive interference, including the $\lambda/4$ and $\lambda/2$ thickness rules for reflective and non-reflective coatings. Visual prompts were used to help them sketch light rays reflecting from thin films and identify phase shifts at media boundaries (using the rule: phase change of π occurs when light reflects off a medium of higher refractive index).

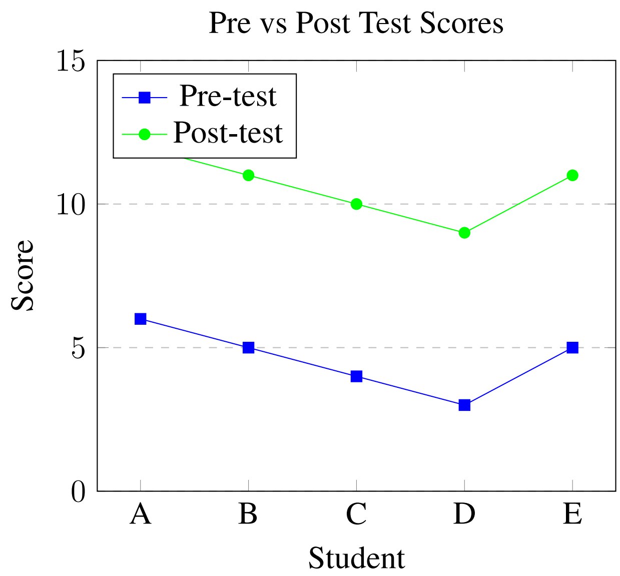
In Session 2, guided problem-solving was implemented. Students completed progressively scaffolded questions in pairs, then independently. Each question emphasized drawing ray paths, annotating phase changes, and applying correct interference conditions. The teacher facilitated by checking diagrams and asking probing questions. A pre-test and post-test of five structured questions (3 marks each) were used to evaluate learning.

Results, Analysis and Discussion

Student	Pre-test Score (/15)	Post-test Score (/15)	Normalized Gain
A	6	12	0.75
B	5	11	0.75
C	4	10	0.75
D	3	9	0.75
E	5	11	0.75

Normalized gain was calculated using:

$$g = \frac{\text{Post} - \text{Pre}}{15 - \text{Pre}}$$



All students showed strong normalized gains ($g = 0.75$), indicating a highly effective intervention. The strategy of having students annotate light ray diagrams with phase changes and calculate net phase difference using reasoning rather than rote formulas proved valuable. Misconceptions such as always assuming constructive interference occurs at integer multiples of λ were successfully corrected through scaffolded drawing tasks. Peer discussion helped students articulate reasoning and confront faulty assumptions.

Conclusion

This low-tech, structured intervention demonstrated that deep understanding of thin film interference can be achieved through focused conceptual tasks and guided reasoning. Drawing-based analysis, step-by-step scaffolding, and targeted peer discussion enabled students to internalize the conditions for interference in thin films. This method can be adapted for other wave optics topics and used effectively even in resource-constrained settings.

Appendix A: Pre and Post Test Questions

1. State the condition for destructive interference in a thin film with one phase change upon reflection.
2. A film of refractive index 1.5 is coated on glass (n = 1.6). What minimum thickness will produce constructive interference for $\lambda = 600$ nm?
3. Draw and label the ray diagram for light reflecting off a soap film (n = 1.33) in air. Indicate where phase changes occur.
4. Explain why some coatings reduce reflection while others enhance it.
5. A non-reflective coating is applied to glass for green light ($\lambda = 550$ nm in vacuum). Find the optimal coating thickness.

Appendix B: Marking Scheme with Step-by-step Solutions

Q1 Destructive interference condition with one phase change: $2t = m\lambda/n$ (1 mark for stating phase change) + (1 mark correct formula) + (1 mark explanation)

Q2 Constructive: one phase change $\rightarrow 2t = (m + 1/2)\lambda/n$ for $m = 0 \rightarrow t = \lambda/(4n) = 600/(4 \times 1.5) = \boxed{100 \text{ nm}}$ (3 marks)

Q3 Ray diagram with correct direction, two reflected rays, one phase change indicated $\rightarrow$ 1 mark each

Q4 Conceptual explanation: destructive interference at specific thickness reduces net reflection (3 marks)

Q5 $t = \lambda/(4n) = 550/(4 \times 1.38) = \boxed{99.6 \text{ nm}}$ (3 marks)

Appendix C: Worksheet Tasks with Answers

1. In a film of refractive index 1.33 in air, how many phase changes occur for normal incidence?

   One, at first reflection

2. Identify whether interference is constructive or destructive for $t = \lambda/4n$ in above case.

   Destructive (1 phase change)

3. Draw a ray diagram for light reflecting off a film between air and glass. Label media, rays, and phase changes.

   Sample sketch with annotations

4. A film is observed to appear blue under white light. What can be inferred about its thickness relative to blue wavelength?

   It satisfies constructive interference condition for blue light

5. A coating reduces glare from lenses. What condition must be satisfied by its thickness?

   $t = \lambda/(4n)$ for destructive interference at design wavelength