Oberlin College Physics 212, Fall 2021

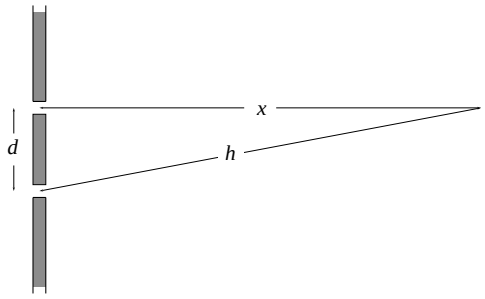
Model Solutions to Assignment 4

1. Strength to Love

The metaphor is valid. Interference shows that light plus light can sum to darkness — just as an electric field of 5 N/C west added to an electric field of 5 N/C east sum to an electric field of 0 N/C. But darkness plus darkness cannot sum to light, because an electric field of 0 N/C added to an electric field of 0 N/C will always produce an electric field of 0 N/C.

⟦*Grading:* Any reasonable argument earns 10 points — full credit. But for full credit there must be an argument. Simply stating "The metaphor is valid" earns only 3 points.⟧

2. Fresnel interference



Suppose $x \gg d$. Then $x \approx h$, so both paths x and h hold the same number of wavelengths, and there is complete constructive interference.

Now imagine decreasing x gradually to reach the farthest point of complete destructive interference. This will happen when there is one-half more wavelength in h than in x: $h = x + \lambda/2$. In addition, of course, $d^2 + x^2 = h^2$. Solving these two equations simultaneously gives $x = 8.75\lambda$.

⟦Common errors: (1) Employ the formula $d \sin\theta = (m + \frac{1}{2})\lambda$ for complete destructive interference in the Fraunhofer case. This formula is irrelevant because the question doesn't concern the Fraunhofer case. Do *not* force your problem into the Procrustean bed of some formula that you happen to look up. Instead, let the problem itself guide you to its solution. (2) Many experience a strong temptation to introduce some angle θ into this problem. Since the problem gives a length and asks for a length, reject that temptation in light of the problem-solving rule of thumb "Be reluctant to introduce extra symbols."⟧

⟦*Grading:* 2 points for diagram; 3 points for $h = x + \lambda/2$; 3 points for Pythagorean theorem; 2 points for answer $\lambda = 8.75\lambda$.⟧

3. Babinet's principle

The voids in pattern A plus the voids in pattern B sum to make the entire hole. Thus the electric field of the light reaching point P through the voids in pattern A (the "A light") plus the electric field of the light reaching point P through the voids in pattern B (the "B light") sum to make the electric field of light reaching point P through the entire hole.

However, the light reaching point P through the entire hole is zero. Thus the "A light" must cancel the "B light" — complete destructive interference.

Consequently, the electric field due to "A light" must be equal in magnitude but opposite in direction to the electric field due to "B light." (In other words, the "A light" is equal in amplitude but π out of phase to the "B light".) Because light intensity involves the magnitude but not direction of the electric field (the magnitude but not phase of the wave), the intensity of "A light" equals the intensity of "B light".

⟦*Grading:* This is a difficult problem to grade because it's largely a matter of "you get it or you don't". Students earn 3 points for the superposition concept expressed in the first paragraph, 3 points for the destructive interference concept expressed in the second paragraph, 2 points for the idea of "equal in magnitude but opposite in direction" or "same amplitude but π out of phase", and 2 points for saying that this idea implies equal brightness. But a cogent argument that doesn't dissect the argument into exactly these four stages should still earn full credit (10 points).⟧

4. Interference with a mica mask

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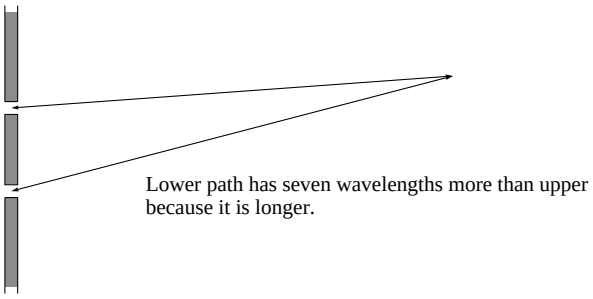

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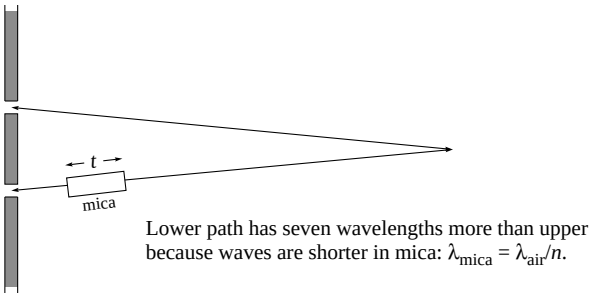

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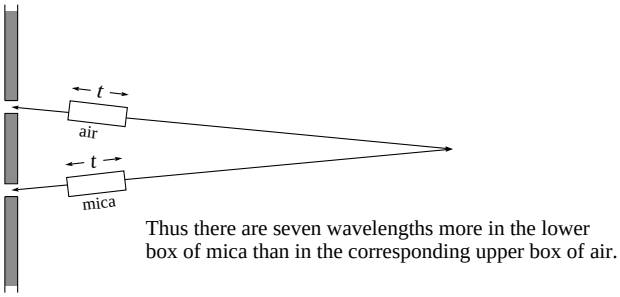

number of wavelengths in air of thickness t is	t/λ
number of wavelengths in mica of thickness t is	$(t/\lambda)n$
so excess number of wavelengths in lower path is	$(t/\lambda)(n-1)$

But this excess number of wavelengths is 7, so

$$t = \frac{7\lambda}{n-1} = 6.65\ \mu\text{m}.$$

⟦*Grading:* 2 points for sketch or words to set up; 1 point for number of wavelengths in air of thickness t; 1 point for number of wavelengths in mica of thickness t; 1 point for realizing that difference is 7; 2 points for equation for t; 1 point for number 6.65; 1 point for three significant figures; 1 point for units.⟧