Chapter 35 End-of-Chapter Problems

Halliday & Resnick, 10th Edition

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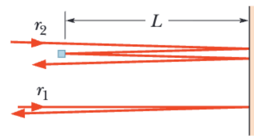
Hit me where it Matters

1 Problem 1



In Fig. 35-31, a light wave along ray r_1 reflects once from a mirror and a light wave along ray r_2 reflects twice from that same mirror and once from a tiny mirror at distance L from the bigger mirror. (Neglect the slight tilt of the rays.) The waves have wavelength 620 nm and are initially in phase. (a) What is the smallest value of L that puts the final light waves exactly out of phase? (b) With the tiny mirror initially at that value of L, how far must it be moved away from the bigger mirror to again put the final waves out of phase?

1.1 Solution (a)

For the two to be completely out of phase, one of the light waves would have to travel half a wavelength more. We can approximate the distance traveled between big and little mirrors to be equivalent to the distance between the big and little mirror.

$$2L = \frac{\lambda}{2} \tag{1}$$

$$L = \frac{\lambda}{4} = \frac{620\,\mathrm{nm}}{4} = \boxed{155\,\mathrm{nm}} \tag{2}$$

1.2 Solution (b)

Replace $\frac{\lambda}{2}$ with $\frac{3\lambda}{2}$.

$$2L_2 = \frac{3\lambda}{2} \tag{3}$$

$$L_2 = \frac{3\lambda}{4} = \frac{3 \times 620\,\mathrm{nm}}{4} = 465\,\mathrm{nm} \tag{4}$$

Now find the change in L.

$$\Delta L = L_2 - L = 465\,\mathrm{nm} - 155\,\mathrm{nm} = \boxed{310\,\mathrm{nm}} \tag{5}$$

2 Problem 3

In Fig. 35-4, assume that two waves of light in air, of wavelength 400 nm, are initially in phase. One travels through a glass layer of index of refraction $n_1 = 1.60$ and thickness L. The other travels through an equally thick plastic layer of index of refraction $n_2 = 1.50$. (a) What is the smallest value L should have if the waves are to end up with a phase difference of 5.65 rad? (b) If the waves arrive at some common point with the same amplitude, is their interference fully constructive, fully destructive, intermediate but closer to fully constructive, or intermediate but closer to fully destructive?

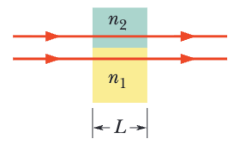


Figure 35-4 Two light rays travel through two media having different indexes of refraction.

2.1 Solution (a)

What matters in this case is the difference in values of kx be equal to 5.65 rad. In both cases, x will be equal to L. We have a known formula for k from λ_n, the latter of which can be found from λ and n.

$$k_1 x - k_2 x = 5.65\,\text{rad} \tag{6}$$

$$L\left(\frac{2\pi}{\lambda/n_1} - \frac{2\pi}{\lambda/n_2}\right) = 5.65\,\text{rad} \tag{7}$$

$$L\,(n_1 - n_2) = \lambda \times \frac{5.65\,\text{rad}}{2\pi\,\text{rad}} \tag{8}$$

$$L = \frac{\lambda}{n_1 - n_2} \times \frac{5.65\,\text{rad}}{2\pi\,\text{rad}} = \frac{400\,\text{nm}}{1.60 - 1.50} \times \frac{5.65\,\text{rad}}{2\pi\,\text{rad}} \tag{9}$$

$$= \frac{400\,\text{nm} \times 5.65}{0.1 \times 2\pi} = \boxed{3.60\,\mu\text{m}} \tag{10}$$

2.2 Solution (b)

Divide the phase difference by 2π.

$$\frac{5.65}{2\pi} = 0.9 \tag{11}$$

This means it is intermediate but closer to fully constructive.

3 Problem 5

How much faster, in meters per second, does light travel in sapphire than in diamond? See Table 33-1 (p. 992).

3.1 Solution

According to table 33-1, the index of refraction of light in sapphire is 1.77, while in diamond it is 2.42. For the speed of light, we use the equation for the speed of light in a medium.

$$c_n = \frac{c}{n} \tag{12}$$

The difference in speeds of light is calculatable by taking the difference between two speeds.

$$\Delta c = c_{\text{sapphire}} - c_{\text{diamond}} = \frac{c}{n_{\text{sapphire}}} - \frac{c}{n_{\text{diamond}}} = c\left(\frac{1}{1.77} - \frac{1}{2.42}\right) \tag{13}$$

$$= c\,(0.1517) = \boxed{45.5 \times 10^6\ \text{m/s}} \tag{14}$$

4 Problem 9

In Fig. 35-4, assume that the two light waves, of wavelength 620 nm in air, are initially out of phase by π rad. The indexes of refraction of the media are $n_1 = 1.45$ and $n_2 = 1.65$. What are the (a) smallest and (b) second smallest value of L that will put the waves exactly in phase once they pass through the two media?

4.1 Solution (a)

What matters in this case is the difference in values of kx be equal to π rad. In both cases, x will be equal to L. We have a known formula for k from λ_n, the latter of which can be found from λ and n.

$$k_1x - k_2x = L\left(\frac{2\pi}{\lambda/n_1} - \frac{2\pi}{\lambda/n_2}\right) = \pi \tag{15}$$

$$L(n_1 - n_2) = \frac{\lambda}{2} \tag{16}$$

$$L = \left|\frac{620\,\text{nm}}{2(1.45 - 1.65)}\right| = \frac{620\text{nm}}{0.4} = \boxed{1.55\,\mu\text{m}} \tag{17}$$

4.2 Solution (b)

Since we're going from π to 3π, just multiply it by 3.

$$3 * 1.55\,\mu\text{m} = \boxed{4.650\,\mu\text{m}} \tag{18}$$

5 Problem 15

5.1 Solution

6 Problem 17

6.1 Solution

7 Problem 19

7.1 Solution

8 Problem 23

8.1 Solution

9 Problem 25

9.1 Solution

10 Problem 27

10.1 Solution

11 Problem 29

11.1 Solution

12 Problem 31

12.1 Solution

13 Problem 35

13.1 Solution

14 Problem 39

14.1 Solution

15 Problem 43

15.1 Solution

16 Problem 45

16.1 Solution

17 Problem 51

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19 Problem 69

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