Chapter 35 End-of-Chapter Problems

Halliday & Resnick, 10th Edition

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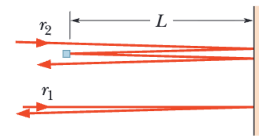
Hit me where it Matters

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.

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

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

1.2 Solution (b)

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

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

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

Now find the change in L.

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

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?

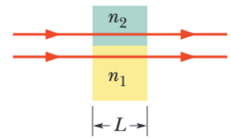


Figure 35-4 Two light rays travel through two media having different indexes of refraction.

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.

$$k_1x - k_2x = 5.65\,\text{rad} \tag{6}$$

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

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

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

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

2.2 Solution (b)

Divide the phase difference by 2π.

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

This means it is <u>intermediate but closer to fully constructive</u>.

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

A double-slit arrangement produces interference fringes for sodium light ($\lambda = 589\,\text{nm}$) that have an angular separation of $3.50 \times 10^{-3}\,\text{rad}$. For what wavelength would the angular separation be 10.0% greater?

5.1 Solution

10% greater than the current angular separation is $3.85 \times 10^{-3}\,\text{rad}$. We can develop a ratio of the initial equation from Young's experiment and the other case of the equation.

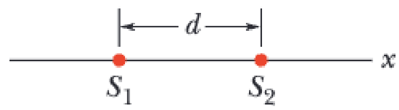
$$\frac{d\,\sin\theta_2}{d\,\sin\theta_2} = \frac{m_2\lambda_2}{m_1\lambda_1} \tag{19}$$

The value of d does not change, nor does the value of m, so we are left with only the thetas and lambdas and we can solve for the second wavelength.

$$\frac{\sin\theta_2}{\sin\theta_2} = \frac{\lambda_2}{\lambda_1} \tag{20}$$

$$\lambda_2 = \lambda_1\frac{\sin\theta_2}{\sin\theta_2} = 589\,\text{nm} \times \frac{\sin(3.85 \times 10^{-3})}{\sin(3.50 \times 10^{-3})} = \boxed{648\,\text{nm}} \tag{21}$$

6 Problem 17



In Fig. 35-37, two radio-frequency point sources S_1 and S_2, separated by distance $d = 2.0\,\mathrm{m}$, are radiating in phase with $\lambda = 0.50\,\mathrm{m}$. A detector moves in a large circular path around the two sources in a plane containing them. How many maxima does it detect?

6.1 Solution

For my first half of my reasoning, see my answer to Chapter 17 Problem 19 (Week 37).

$$\frac{\Delta L}{\lambda} \equiv 0.5 \mod 1 \tag{22}$$

$$0 \leq \Delta L < d \tag{23}$$

$$0 \leq \frac{\Delta L}{\lambda} < 2d \tag{24}$$

$$0 \leq \frac{L}{\lambda} < 4 \tag{25}$$

There are four cases of this. Multiply this by four quarter-circles to get the answer of $\boxed{16}$.

7 Problem 19

Suppose that Young's experiment is performed with blue-green light of wavelength 500 nm. The slits are 1.20 mm apart, and the viewing screen is 5.40 m from the slits. How far apart are the bright fringes near the center of the interference pattern?

7.1 Solution

Use the small angle approximation $\sin\theta \approx \theta \approx \tan\theta$. We can put this into the equation for the bright fringes in Young's interference experiment.

$$d\tan\theta = d\frac{\Delta y}{D} = \lambda \tag{26}$$

$$\Delta y = \frac{\lambda D}{d} = \frac{500\,\mathrm{nm} \times 5.40\,\mathrm{m}}{1.20\,\mathrm{mm}} = \boxed{2.25\,\mathrm{mm}} \tag{27}$$

8 Problem 23

In Fig. 35-38, sources A and B emit long-range radio waves of wavelength 400 m, with the phase of the emission from A ahead of that from source B by 90°. The distance r_A from A to detector D is greater than the corresponding distance r_B by 100 m. What is the phase difference of the waves at D?

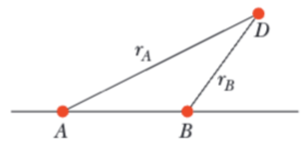


Figure 35-38 Problem 23.

8.1 Solution

$\boxed{0}$

9 Problem 25

In Fig. 35-40, two isotropic point sources of light (S_1 and S_2) are separated by distance 2.70 μm along a y axis and emit in phase at wavelength 900 nm and at the same amplitude. A light detector is located at point P at coordinate x_P on the x axis. What is the greatest value of x_P at which the detected light is minimum due to destructive interference?

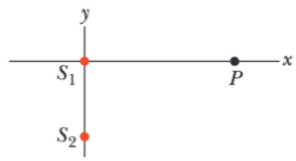


Figure 35-40 Problems 25 and 28.

9.1 Solution

Pretend it's Young's experiment.

$$d\frac{y}{D} = \frac{\lambda}{2} \tag{28}$$

$$D = \frac{2yd}{\lambda} = \frac{2 \times 1.35 \times 10^{-6}\,\mathrm{m} \times 2.70 \times 10^{-6}\,\mathrm{m}}{900 \times 10^{-9}\,\mathrm{m}} = \boxed{8.1 \times 10^{-6}\,\mathrm{m}} \tag{29}$$

10 Problem 27

A thin flake of mica (n = 1.58) is used to cover one slit of a double-slit interference arrangement. The central point on the viewing screen is now occupied by what had been the seventh bright side fringe (m = 7). If $\lambda = 550\,\mathrm{nm}$, what is the thickness of the mica?

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

17.1 Solution

18 Problem 63

18.1 Solution

19 Problem 69

19.1 Solution

20 Problem 71

20.1 Solution

21 Problem 73

21.1 Solution

22 Problem 75

22.1 Solution

23 Problem 85

23.1 Solution

24 Problem 91

24.1 Solution

25 Problem 103

25.1 Solution

Contents