Wave Nature of Light

Advanced Placement Physics B
Mr. DiBucci

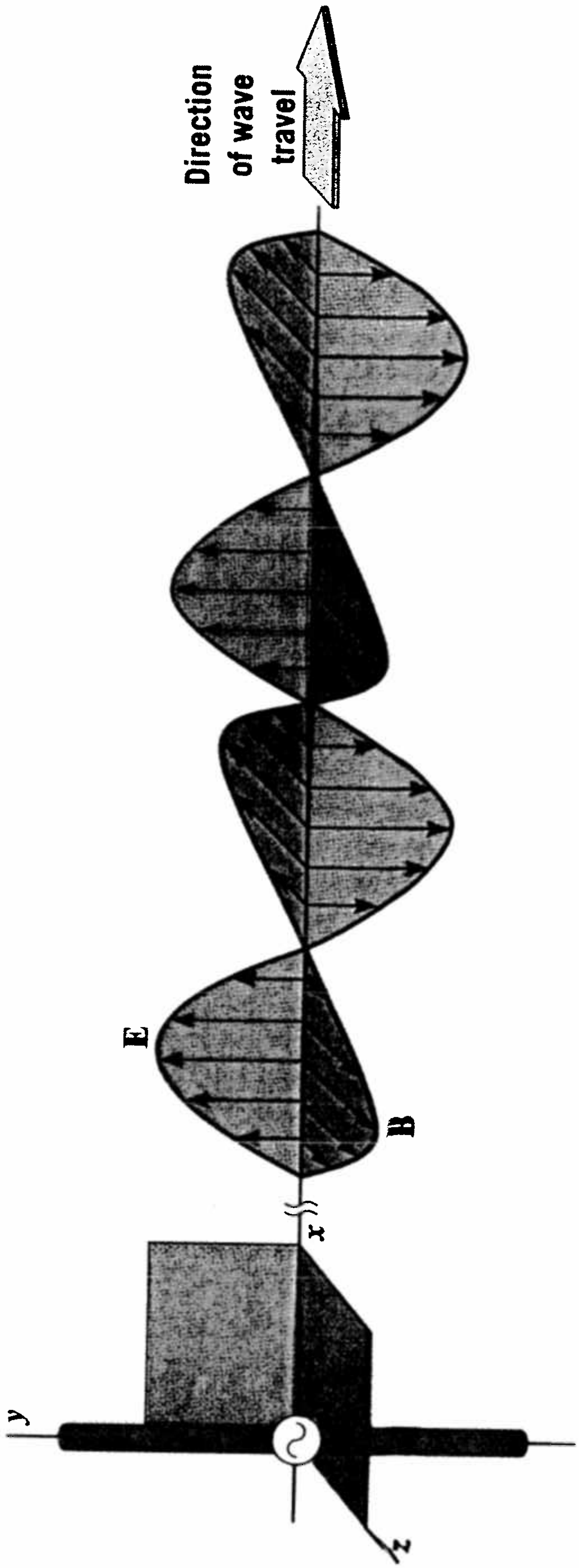


FIGURE 24-4

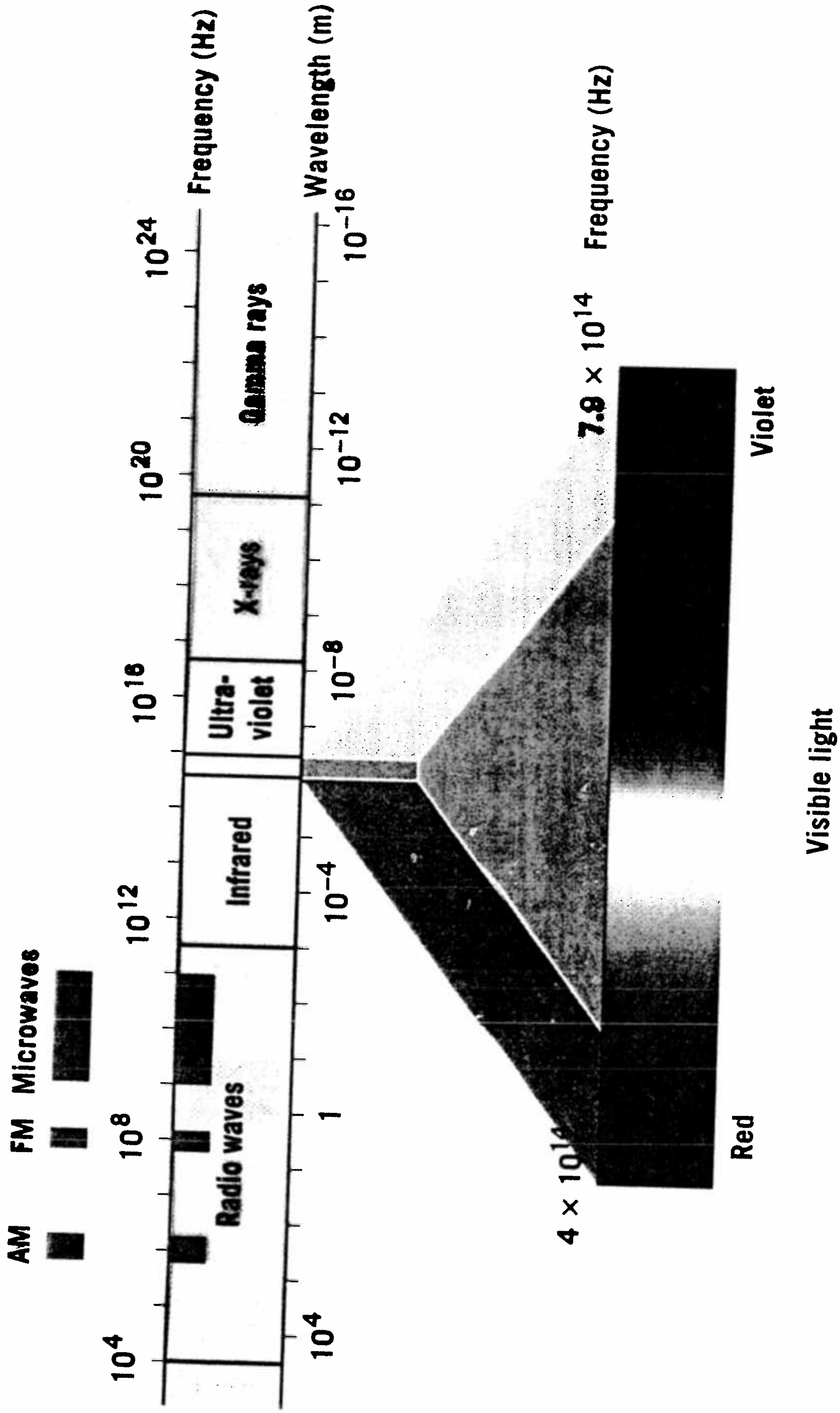

AM
FM
Microwaves
10^4
10^8
10^{12}
10^{16}
10^{20}
10^{24}
Frequency (Hz)
Radio waves
Infrared
Ultra-violet
X-rays
Gamma rays
10^4
1
10^{-4}
10^{-8}
10^{-12}
10^{-16}
Wavelength (m)
4×10^{14}
7.9×10^{14}
Frequency (Hz)
Red
Violet
Visible light

FIGURE 24-9

DIBUCCI

Section 24.1 The Nature of Electromagnetic Waves

1. **ssm** In astronomy, distances are often expressed in light-years. One light-year is the distance traveled by light in one year. The distance to Alpha Centauri, the closest star other than our own sun that can be seen by the naked eye, is 4.3 light-years. Express this distance in meters.

2. (a) Neil A. Armstrong was the first person to walk on the moon. The distance between the earth and the moon is 3.85×10^8 m. Find the time it took for his voice to reach earth via radio waves. (b) Determine the communication time for the first person who will some day walk on Mars, which is 5.6×10^{10} m from earth at the point of closest approach.

X. In Figure 24.5 the value of the inductance is 2.6×10^{-4} H. For an AM radio station broadcasting at a frequency of 1200 kHz, find the value to which the capacitance must be adjusted.

X. For an FM radio station broadcasting at a frequency of 88.0 MHz, the capacitance in Figure 24.5 must be adjusted to a value of 33.0×10^{-12} F. Assuming the inductance does not change, determine the value of the capacitance for an FM station broadcasting at 108.0 MHz.

5. **ssm** Equation 16.3, $y = A \sin(2\pi ft - 2\pi x/\lambda)$, gives the mathematical representation of a wave oscillating in the y direction and traveling in the positive x direction. Let y in this equation equal the electric field of an electromagnetic wave traveling in a vacuum. The maximum electric field is $A = 156$ N/C, and the frequency is $f = 1.50 \times 10^8$ Hz. Plot a graph of the electric field strength versus position, using for x the following values: 0, 0.50, 1.00, 1.50, and 2.00 m. Plot this graph for (a) a time $t = 0$ and (b) a time t that is one-fourth of the wave's period.

ection 24.2 The Electromagnetic Spectrum

7. Some of the X-rays produced in an X-ray machine have wavelength of 2.1 nm. What is the frequency of these electromag netic waves?

8. A truck driver is broadcasting at a frequency of 26.965 MH with a CB (citizen's band) radio. Determine the wavelength of th electromagnetic wave being used.

9. **ssm www** Television sets sometimes use a "rabbit-ears antenna. A rabbit-ears antenna consists of a pair of metal rods The length of each rod can be adjusted to be one-quarter of wavelength of an electromagnetic wave whose frequency i 60.0 MHz. How long is each rod?

10. Magnetic resonance imaging or MRI (see Section 21.7 and positron emission tomography or PET scanning (see Sectio 32.6) are two medical diagnostic techniques. Both employ electro magnetic waves. For these waves, find the ratio of the MRI wave length (frequency = 6.38×10^7 Hz) to the PET scanning wave length (frequency = 1.23×10^{20} Hz).

11. A radio station broadcasts a radio wave whose wavelength i 274 m. (a) What is the frequency of the wave? (b) Is this radio wave AM or FM? (See Figure 24.9.)

12. Obtain the wavelengths in vacuum for (a) blue light with a frequency of 6.34×10^{14} Hz and (b) orange light with a frequency of 4.95×10^{14} Hz. Express your answers in nanometers (nm).

13. **ssm** The human eye is most sensitive to light having a frequency of about 5.5×10^{14} Hz, which is in the yellow-green region of the electromagnetic spectrum. How many wavelengths of this light can fit across the width of your thumb, a distance of about 2.0 cm?

14. Section 17.5 deals with transverse standing waves on a string. Electromagnetic waves also can form standing waves. In a standing wave pattern formed from microwaves, the distance between a node and an adjacent antinode is 0.50 cm. What is the microwave frequency?

Section 24.3 The Speed of Light

15. Ghost images are formed in a TV picture when the electromagnetic wave from the broadcasting antenna reflects from a building or other large object and arrives at the TV set shortly after the wave coming directly from the broadcasting antenna. If the reflected wave arrives 5.0×10^{-7} s after the direct wave, what is the difference in the distances traveled by the two waves?

16. In 1980 and 1981, two Voyager spacecraft sent back beautiful photographs of Saturn via radio transmission. If the distance between earth and Saturn was 1.277×10^{12} m, how much time (ir minutes) was required for the transmission?

17. **ssm www** The distance between earth and the moon car be determined from the time it takes for a laser beam to trave from earth to a reflector on the moon and back. If the round trip time can be measured to an accuracy of one-tenth of a nanosecond (1 ns = 10^{-9} s), what is the corresponding error ii the earth–moon distance?

1X. Review Conceptual Example 3 before attempting this prob lem. The brightest star in the night sky is Sirius, which is at a dis tance of 8.3×10^{16} m. When we look at this star, how far back i time are we seeing it? Express your answer in years. (There ar $365\frac{1}{4}$ days in one year.)

19. A communications satellite is in a synchronous orbit that i 3.6×10^7 m directly above the equator. The satellite is locate midway between Quito, Equador, and Belém, Brazil, two citie almost on the equator that are separated by a distance of 3.5 > 10^6 m. Find the time it takes for a telephone call to go by way c satellite between these cities. Ignore the curvature of the earth.

2X. Figure 24.11 illustrates Michelson's setup for measuring th speed of light with the mirrors placed on Mt. San Antonio and M Wilson in California, which are 35 km apart. Using a value c 3.00×10^8 m/s for the speed of light, find the minimum angul speed (in rev/s) for the rotating mirror.

1. 4.1×10^{16} m
2. 1.28 s, 1.9×10^2 s
3) skip
4) skip
5) see solution manual
7) 1.4×10^{17} Hz
8) 11.12 m
9) 1.25 m
10) 1.93×10^{12}
11) 1.09×10^6 Hz AM
12) 473 nm, 606 nm
13) 3.7×10^4
14) 1.5×10^{10} Hz
15) 150 m
16) 70.9 min
17) 0.015 m
18) 8.8 yrs
19) 0.24 s
20) 540 rev/sec

Name____ per ____ date ______
AP Physics B DiBucci
Thin Film Interference
Worksheet 1

1. (a) A thin film of gasoline floats on a puddle of water. Sunlight falls almost perpendicularly on the film and reflects into your eyes. Although sunlight is white, since it contains all colors, the film has a yellow hue, because destructive interference eliminates the color of blue (λ_{vacuum} = 469 nm) from the reflected light. If the refractive indices of the blue light in gasoline and water are 1.40 and 1.33, respectively, determine the minimum nonzero thickness t of the film. (b) Repeat part (a) assuming that the gasoline is on glass (n_{glass} = 1.52) instead of water.

a) 168nm
b) 83.8nm

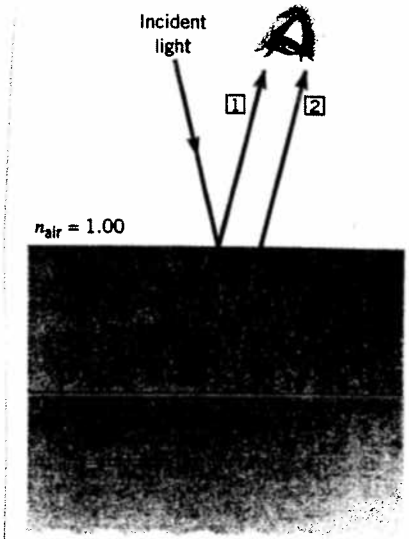
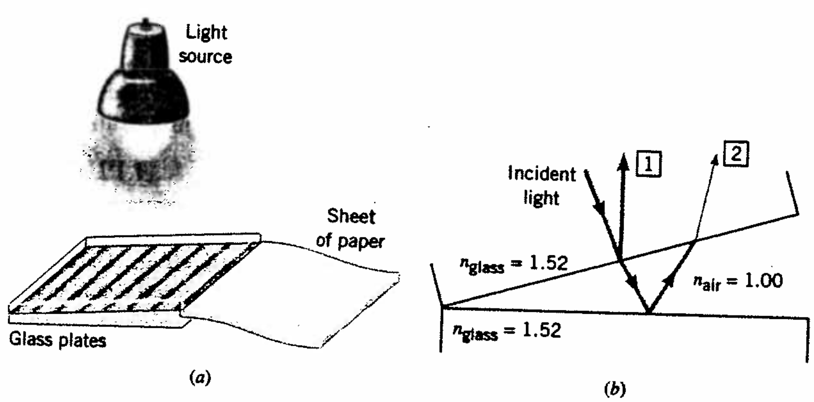


Figure 27.12 Because of reflection and refraction, two light waves, represented by rays 1 and 2, enter the eye when light shines on a thin film of gasoline floating on a thick layer of water.

2. (a) Assuming that green light (λ_{vacuum} = 552 nm) strikes the glass plates nearly perpendicularly in Figure 27.15, determine the number of bright fringes that occurs between the place where the plates touch and the edge of the sheet of paper (thickness = 4.10×10^{-5} m). (b) Explain why there is a dark fringe where the plates touch.

a) 149

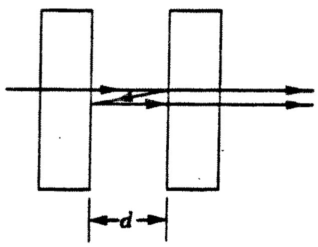
Figure 27.15 (*a*) The wedge of air formed between two flat glass plates causes an interference pattern of alternating dark and bright fringes to appear in reflected light. (*b*) A side view of the glass plates and the air wedge.



Interference in Thin Films

13. Suppose the film shown in Figure 26.8 has an index of refraction of 1.36 and is surrounded by air on both sides. Find the minimum thickness other than zero which will produce constructive interference in the reflected light when illuminated by light of wavelength 500 nm.

14. A beam of light of wavelength 580 nm passes through two closely spaced glass plates, as shown
For what minimum nonzero value of the plate separation, d, will the transmitted light be bright?



15. A planoconvex lens rests with its curved side on a flat glass surface and is illuminated from above by light of wavelength 500 nm. It is observed that there is a dark spot at the center surrounded by 19 concentric dark rings (with bright rings in between). How much thicker is the air wedge at the position of the 19th dark ring than at the center?

16. An oil film 500 nm thick floats on water. It is illuminated with white light in the direction perpendicular to the film. What wavelengths will be strongly reflected in the range from 300 nm to 700 nm? Take $n = 1.46$ for oil.

17. Two rectangular optically flat plates ($n = 1.52$) are in contact along one end and are separated along the other end by a sheet of paper that is 4×10^{-3} cm thick. The top plate is illuminated by monochromatic light of wavelength 546.1 nm. Calculate the number of dark parallel bands crossing the top plate (including the dark band at zero thickness along the edge of contact between the two plates).

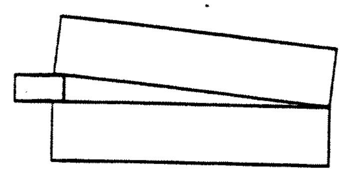


FIGURE 26.30

18. A hair replaces the sheet of paper in Problem 17 [redacted], and when the reflected light is viewed, it is found that seven dark bands (including the one along the edge of contact) cross the top plate, with the seventh being directly over the hair. What is the thickness of the hair? The wavelength of light remains the same.

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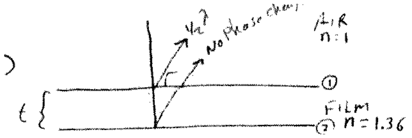
13. 91.9 nm
14. 290 nm
15. 4750 nm
16. 324 nm, 417 nm, 584 nm
17. 147
18. 1640 nm

Solutions

$\lambda_{vac} = 500nm$

* Solutions to THIN FILM Interference work sheet

13)



AIR n=1

Constructive

Since there is a ½ λ film shift at ① then use

$2t = (m+\frac{1}{2})\lambda_{Film}$ let m = 0

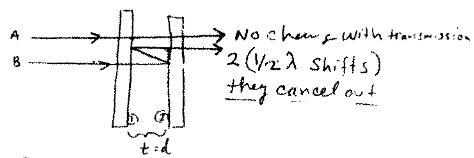
$t = \frac{\frac{1}{2}\lambda_{Film}}{2}$

$= \frac{1}{4}\frac{\lambda_{VAC}}{1.36} = \frac{1}{4}\frac{500nm}{1.36} =$ **91.9 nm**

14) $\lambda_{VAC} = 580nm$

$\lambda_{Fim} = \frac{580nm}{1}$

$\lambda_{Fim} = 580nm$

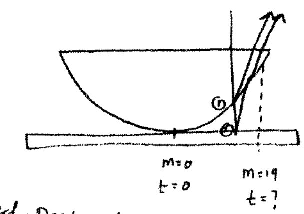


* need constructive Interference

$2t = m\lambda_{Film}$

$t = \frac{m\lambda_{Film}}{2} = \frac{1 \cdot 580nm}{2} =$ **290 nm**

15)



* we need Destructive Interference

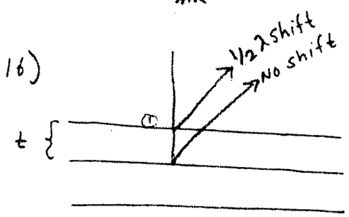
* No phase shift w/ FIRST RAY
* ½λ phase shift w/ 2nd RAY

$t = \left(\frac{19}{2}\right)\left(\frac{500nm}{1.0}\right) =$ **4750 nm**

$2t = m\lambda_{Film}$

$t = \frac{m}{2}\frac{\lambda_{VAC}}{n_{AIR}}$

16)



AIR n = 1

OIL n = 1.46 (t_{Fim} = 500nm)

water n = 1.33

* need constructive interference

$2t = (m+\frac{1}{2})\lambda_{Film}$

$2t = (m+\frac{1}{2})\frac{\lambda_{vac}}{1.46}$

$\lambda_{VAC} = \frac{2t(1.46)}{(m+\frac{1}{2})} = \frac{2(500nm)(1.46)}{(m+\frac{1}{2})} = \frac{1460nm}{(m+\frac{1}{2})} =$

let m = 0, 1, 2, 3 . . . .

when m =	λ =
0	2920nm
1	973nm
2	584nm
3	417nm
4	324 nm
5	265 nm

Keep 584 nm, 417 nm, 324 nm

Section 27.1 The Principle of Linear Superposition, Section 27.2 Young's Double-Slit Experiment

1. **ssm** The transmitting antenna for a radio station is 7.00 km from your house. The frequency of the electromagnetic wave broadcast by this station is 536 kHz. The station builds a second transmitting antenna that broadcasts an identical electromagnetic wave in phase with the original one. The new antenna is 8.12 km from your house. Does constructive or destructive interference occur at the receiving antenna of your radio? Show your calculations.

2. Two sources are in phase and emit waves that have a wavelength of 0.44 m. Determine whether constructive or destructive interference occurs at a point whose distances from the two sources are as follows: (a) 1.32 and 3.08 m; (b) 2.67 and 3.33 m; (c) 2.20 and 3.74 m; (d) 1.10 and 4.18 m. *

3. A Young's double-slit experiment is performed using light that has a wavelength of 630 nm. The separation between the slits is 5.3×10^{-5} m. Find the angles that locate the (a) first-, (b) second-, and (c) third-order bright fringes on the screen.

4. In a Young's double-slit experiment, the angle that locates the second dark fringe on either side of the central bright fringe is 5.4°. Find the ratio of the slit separation d to the wavelength λ of the light.

5. **ssm** A flat observation screen is placed at a distance of 4.5 m from a pair of slits. The separation on the screen between the central bright fringe and the first-order bright fringe is 0.037 m. The light illuminating the slits has a wavelength of 490 nm. Determine the slit separation.

6. In Young's double-slit experiment, blue light (λ = 440 nm) gives a second-order bright fringe at a certain location on a flat screen. What wavelength of visible light would produce a dark fringe at the same location? Assume that the range of visible wavelengths extends from 380 to 750 nm.

***7.** In a Young's double-slit experiment the separation y between the first-order bright fringe and the central bright fringe on a flat screen is 0.0240 m, when the light has a wavelength of 475 nm. Assume that the angles that locate the fringes on the screen are small enough so that $\sin\theta \approx \tan\theta$. Find the separation y when the light has a wavelength of 611 nm.

***8.** Review Conceptual Example 3 before attempting this problem. Two slits are 0.158 mm apart. A mixture of red light (wavelength = 665 nm) and yellow-green light (wavelength = 565 nm) falls on the slits. A flat observation screen is located 2.24 m away. What is the distance on the screen between the third-order red fringe and the third-order yellow-green fringe?

1) $\lambda = 5.6 \times 10^{2}$ m
CONSTRUCTIVE

2) constructive, Destructive, Constructive, Destructive

3) 0.68°, 1.4°, 2.0°

4) 16

5) 0.47°, 6.0×10^{-5} m

6) 587 nm = 5.87×10^{-7} m

7) 0.0309 m

8) 4.3×10^{-3} m

Section 27.5 Diffraction

21. **ssm** A diffraction pattern forms when light passes through a single slit. The wavelength of the light is 675 nm. Determine the angle that locates the first dark fringe when the width of the slit is (a) 1.8×10^{-4} m and (b) 1.8×10^{-6} m.

22. How wide does a single slit have to be before the angle locating the first-order dark fringe is equal to 0.10°, when the wavelength of the light is 660 nm?

23. A single slit has a width of 2.1×10^{-6} m and is used to form a diffraction pattern. Find the angle that locates the second dark fringe when the wavelength of the light is (a) 430 nm and (b) 660 nm.

24. A slit whose width is 4.30×10^{-5} m is located 1.32 m from a flat screen. Light shines through the slit and falls on the screen. Find the width of the central fringe of the diffraction pattern when the wavelength of the light is 635 nm.

25. **ssm www** Light shines through a single slit whose width is 5.6×10^{-4} m. A diffraction pattern is formed on a flat screen located 4.0 m away. The distance between the middle of the central bright fringe and the first dark fringe is 3.5 mm. What is the wavelength of the light?

26. A single slit is illuminated by monochromatic light ($\lambda_{\text{vacuum}} = 645$ nm). The width of the slit is 4.85×10^{-6} m. The region between the slit and screen is filled with water ($n = 1.33$). Determine the angular width 2θ of the central bright fringe.

***27.** The width of a slit is 2.0×10^{-5} m. Light with a wavelength of 480 nm passes through this slit and falls on a screen that is located 0.50 m away. In the diffraction pattern, find the width of the bright fringe that is next to the central bright fringe.

***28.** Light of wavelength 665 nm is incident on a single slit. The central bright fringe is 2.60 cm wide on a flat screen that is 63.0 cm from the slit. What would be the width of the central bright fringe if the wavelength were 425 nm?

***29.** **ssm** The central bright fringe in a single-slit diffraction pattern has a width that equals the distance between the screen and the slit. Find the ratio λ/W of the wavelength of the light to the width of the slit.

****30.** In a single-slit diffraction pattern, the central fringe is 450 times wider than the slit. The screen is 18 000 times farther from the slit than the slit is wide. What is the ratio λ/W, where λ is the wavelength of the light shining through the slit and W is the width of the slit? Assume that the angle that locates a dark fringe on the screen is small, so that $\sin\theta \approx \tan\theta$.

21) 0.21°, 22°
22) 3.8×10^{-4} m
23) 24°, 39°
24) 0.0390 m
25) 490 NM
26) 11.5°
27) 0.012 m
28) 1.66 cm
29) 0.447
30) 0.013

Section 27.7 The Diffraction Grating, Section 27.8 Compact Discs and the Use of Interference

41. **ssm** The diffraction gratings discussed in the text are transmission gratings, because light *passes through* them. There are also gratings in which the light *reflects from* the grating to form a pattern of fringes. Equation 27.7 also applies to a reflection grating with straight parallel lines when the incident light shines perpendicularly on the grating. The surface ot a compact disc (CD) has a multicolored appearance because it acts like a reflection grating and spreads sunlight into its colors. The arms of the spiral track on the CD are separated by 1.1×10^{-6} m. Using Equation 27.7, estimate the angle that corresponds to the first-order maximum for a wavelength of (a) 660 nm (red) and (b) 410 nm (violet).

42. Atomic hydrogen emits two waves whose wavelengths are 656 and 410.0 nm. The waves fall on a grating that has 5310 lines/cm. What is the angular separation, $\theta_{656} - \theta_{410}$, of the waves in the second-order maximum?

43. A diffraction grating produces a first-order bright fringe that is 0.0894 m away from the central bright fringe on a flat screen. The separation between the slits of the grating is 4.17×10^{-6} m, and the distance between the grating and the screen is 0.625 m. What is the wavelength of the light shining on the grating?

44. When a grating is used with light that has a wavelength of 621 nm, a third-order maximum is formed at an angle of 18.0°. How many lines per centimeter does this grating have?

45. **ssm** The wavelength of the laser beam used in a compact disc player is 790 nm. Suppose that a diffraction grating produces first-order tracking beams that are 1.2 mm apart at a distance of 3.0 mm from the grating. Estimate the spacing between the slits of the grating.

46. A grating and an observation screen are fixed in position. For a wavelength λ_1, adjacent principal maxima are separated on the screen by 2.7 cm. For another wavelength λ_2, the same principal maxima are separated by 3.2 cm. Find the ratio λ_2/λ_1, assuming that the screen is far enough from the grating that $\sin\theta \approx \tan\theta$.

41) 37°
42) 18.3°
43) 5.9×10^{-7} m
44) 1660 lines/cm
45) 4.0×10^{-6} m
46) 1.2

34) 640 Hz

35) Receding, 1.8×10^6 m/s

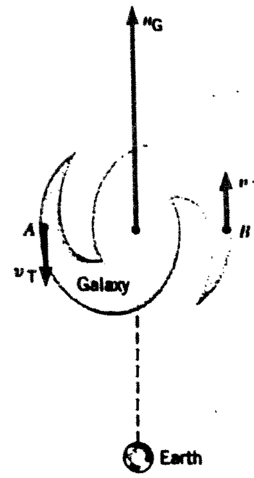
38) 62 %

39) 0.555 W/m², 3.7×10^{-2} W/m²

40) 0°, 45°

41) 0.82, 0.18

42) 811 W/m², 681 W/m²



Section 24.5 The Doppler Effect and Electromagnetic Waves

34. Suppose that the police car in Example 6 is moving to the right at 27 m/s, while the speeder is coming up from behind at a speed of 39 m/s, both speeds being with respect to the ground. Assume that the electromagnetic wave emitted by the radar gun has a frequency of 8.0×10^9 Hz. (a) Find the magnitude of the difference between the frequency of the emitted wave and the wave that returns to the police car after reflecting from the speeder's car. (b) Which wave has the greater frequency? Why?

35. A distant galaxy emits light that has a wavelength of 500.7 nm. On earth, the wavelength of this light is measured to be 503.7 nm. (a) Decide whether this galaxy is approaching or receding from the earth. Give your reasoning. (b) Find the speed of the galaxy relative to the earth.

36. When the source and observer of electromagnetic waves approach one another at a relative speed u that is an appreciable fraction of the speed of light, Equation 24.6 does not give the correct Doppler effect. Instead, the correct expression is $f' = f\sqrt{(1 + u/c)/(1 - u/c)}$. Find the ratio u/c, such that the observed frequency f' is twice the emitted frequency f.

*37. ssm A distant galaxy is simultaneously rotating and receding from the earth. As the drawing shows, the galactic center is receding from the earth at a relative speed of $u_G = 1.6 \times 10^6$ m/s. Relative to the center, the tangential speed is $v_T = 0.4 \times 10^6$ m/s for locations A and B, which are equidistant from the center. When the frequencies of the light coming from regions A and B are measured on earth, they are not the same and each is different than the emitted frequency of 6.200×10^{14} Hz. Find the measured frequency for the light from (a) region A and (b) region B.

Section 24.6 Polarization

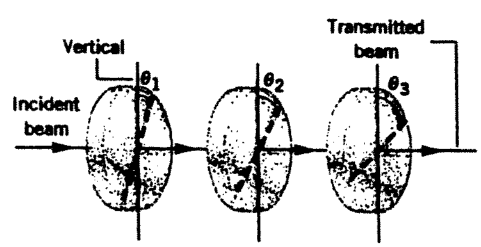
38. Polarized light strikes a piece of polarizing material. The incident light is polarized at an angle of 38° relative to the transmission axis of the material. What percentage of the light intensity is transmitted?

39. Unpolarized light whose intensity is 1.10 W/m² is incident on the polarizer in Figure 24.20. (a) What is the intensity of the light leaving the polarizer? (b) If the analyzer is set at an angle $\theta = 75°$ with respect to the polarizer, what is the intensity of the light that reaches the photocell?

40. What should be the angle between the transmission axes of the polarizer and the analyzer in Figure 24.20, so the polarized light reaching the photocell has an intensity that is (a) one-half and (b) one-fourth of the intensity of the incident unpolarized light?

41. ssm Linearly polarized light is incident on a piece of polarizing material. What is the ratio of the transmitted light intensity to the incident light intensity when the angle between the transmission axis and the incident electric field is (a) 25° and (b) 65°?

42. The orientation of the transmission axis for each of the three sheets of polarizing material in the drawing is labeled relative to the vertical. A beam of light, polarized in the vertical direction, is incident on the first sheet. The intensity of the incident beam is 1550 W/m². Obtain the intensity of the beam transmitted through the three sheets when: (a) $\theta_1 = 0°$, $\theta_2 = 40.0°$, $\theta_3 = 75.0°$; (b) $\theta_1 = 30.0°$, $\theta_2 = 30.0°$, $\theta_3 = 70.0°$.



Wave Optics

Laboratory Manual

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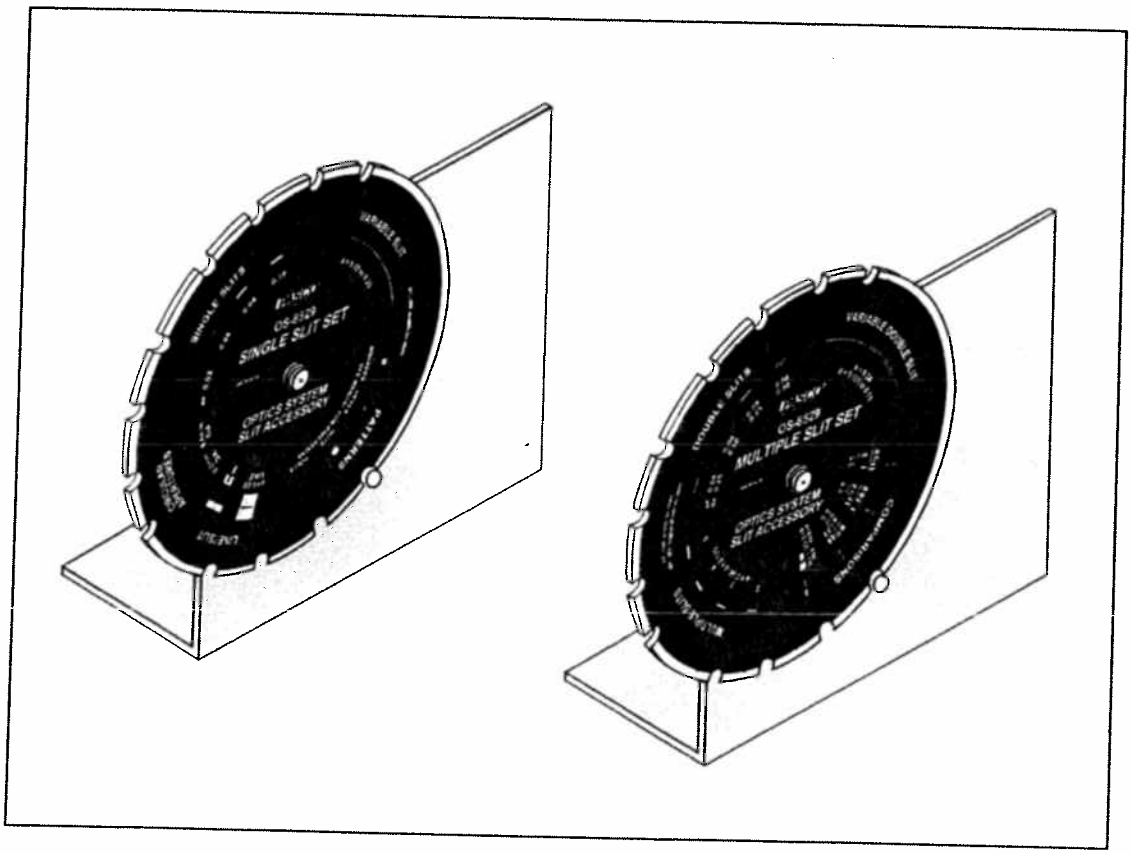

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When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage caused by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

① The shipping carton must be strong enough for the item shipped.

② Make certain there are at least two inches of packing material between any point on the apparatus and the inside walls of the carton.

③ Make certain that the packing material can not shift in the box, or become compressed, thus letting the instrument come in contact with the edge of the shipping carton.

Address: PASCO scientific
10101 Foothills Blvd.
P.O. Box 619011
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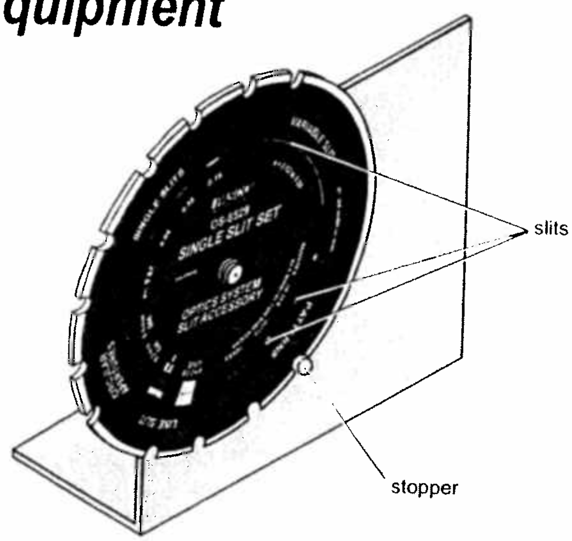
email: techsupp@pasco.com

Introduction

The PASCO OS-8529 Slit Accessory is designed for use with the OS-8528 Diode Laser on the optics bench of the Introductory or Advanced Optics Systems (OS-8500 or OS-9254A). The set of two disks has many different types of slits for diffraction and interference experiments. The special comparison patterns have two different slits spaced close enough together so they can both be illuminated by a single laser beam at the same time, allowing students to compare the two different patterns side-by-side.

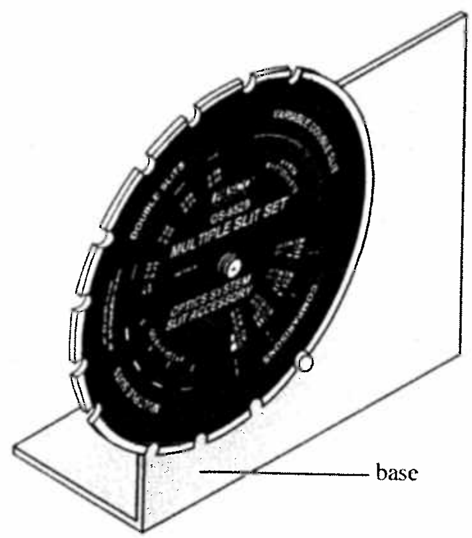
➤ ***NOTE: Due to limitations of the photographic process used to produce the slit film, the line and slit may not be exactly the same width.***

Equipment



Single Slit Set

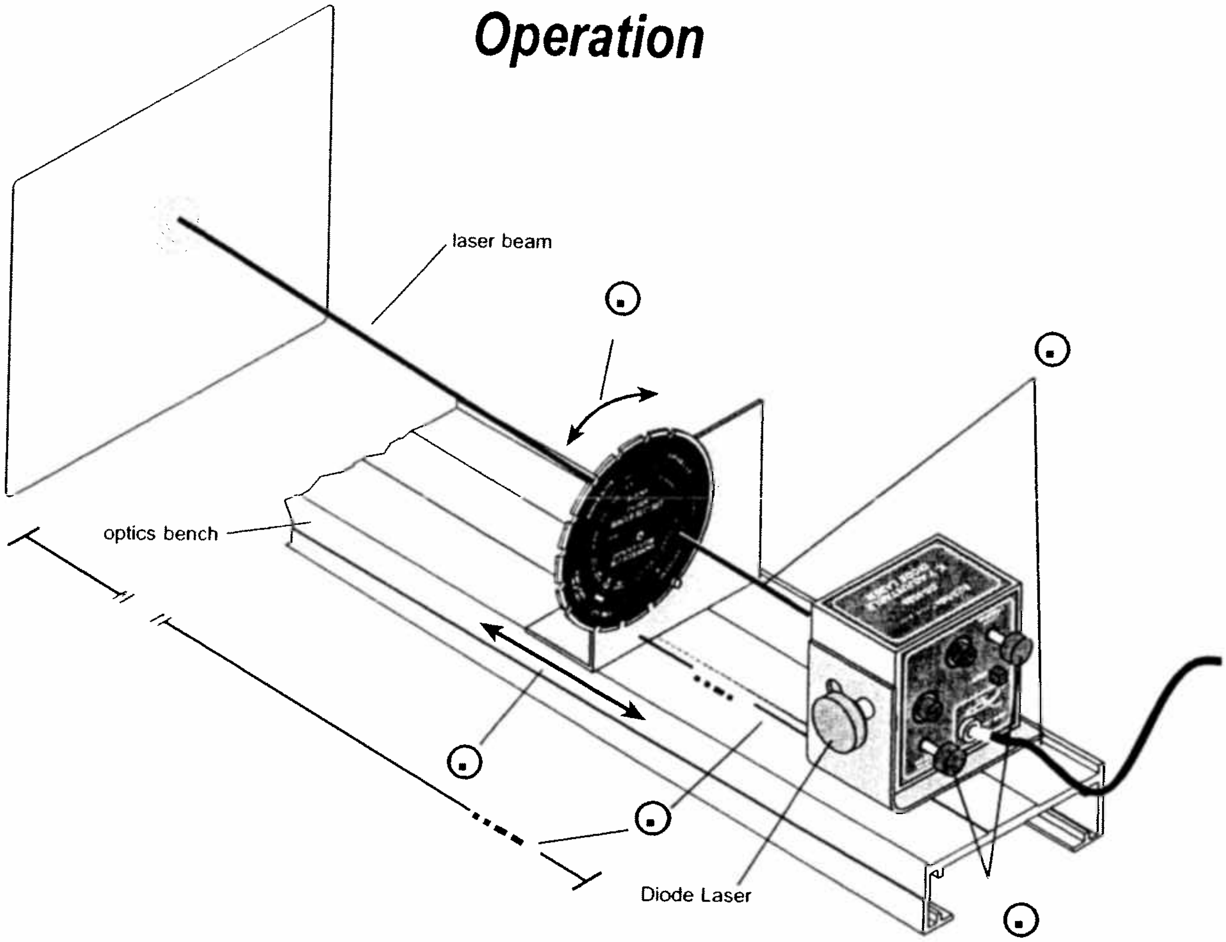
– 4 single slits (slit widths 0.02, 0.04, 0.08, 0.16 mm)
– 1 variable slit (slit width varies from 0.02 to 0.20 mm)
– 1 square pattern
– 1 hexagonal pattern
– 1 random opaque dot pattern (dot diameter = 0.06 mm)
– 1 random hole pattern (hole diameter = 0.06 mm)
– 1 opaque line of width 0.08 mm
– 1 slit/line comparison, line and slit have similar width (0.04 mm)
– 2 circular apertures (diameters 0.2 mm and 0.4 mm)



Multiple Slit Set

– 4 double slits (slit width/separation in mm: 0.04/0.25, 0.04/0.50, 0.08/0.25, 0.08/0.50)
– 1 variable double slit (slit separation varies from 0.125 to 0.75 mm with constant slit width of 0.04 mm)
– 4 comparisons: single/double slit with same slit width (0.04 mm)
– double/double slit with same slit width (0.04 mm), variable separation (0.25 mm – 0.50mm)
– double/double slit with different slit widths (0.04, 0.08 mm), same separation (0.25 mm)
– double/triple slit with same slit width (0.04 mm), same separation (0.125 mm)
– set of 4 multiple slits (2, 3, 4, 5 slits) with same slit width (0.04 mm), same separation (0.125 mm)

Operation



➤ *Note: After the initial adjustment, little or no additional adjustment to the alignment of the laser beam with the slit will be required when you change the slit selection.*

① Place a slit set and the Diode Laser on the magnetic strips of the optics bench about 7 cm apart. Position the optics bench so the Diode Laser is about 1.5 m from a vertical, smooth white projection surface such as a wall, cardboard, etc.

② Align the slit set and the Diode Laser on the optics bench by abutting the edges of the brackets to the side railing of the optics bench.

③ Select the desired slit by rotating the disk until it clicks into place with the slit at approximately the location of the laser beam on the disk.

④ Adjust the alignment of the laser beam with the slit by moving the laser beam up-and-down and back-and-forth with the vertical and horizontal adjustment screws until the diffraction pattern on the projection surface is most intense.

⑤ Slide the slit set back-and-forth slightly to find the position that results in the most intense diffraction pattern.

Experiment 1: Diffraction from a Single Slit

Materials required:

- optics bench[1]
- Diode Laser (OS-8528)
- Single Slit Set (OS-8529)
- white projection surface
- metric rule
- page 2 of the Slit Accessory manual

[1]From the Introductory or Advanced Optics System (OS-8500 or OS-9254A)

Purpose

The purpose of this experiment is to examine the diffraction pattern formed by laser light passing through a single slit and verify that the positions of the minima in the diffraction pattern match the positions predicted by theory.

Theory

When diffraction of light occurs as it passes through a slit, the angle to the minima in the diffraction pattern is given by

$$a \sin \theta = m\lambda \quad (m = 1, 2, 3, \ldots)$$

where a is the slit width, θ is the angle from the center of the pattern to the mth minimum, λ is the wavelength of the light, and m is the order (1 for the first minimum, 2 for the second minimum, . . . counting from the center out). See Figure 1.1.

Since the angles are usually small, it can be assumed that

$$\sin \theta \approx \tan \theta$$

From trigonometry,

$$\tan \theta = \frac{y}{D}$$

where y is the distance on the screen from the center of the pattern to the mth minimum and D is the distance from the slit to the screen as shown in Figure 1.1. The diffraction equation can thus be solved for the slit width:

$$a = \frac{m\lambda D}{y} \quad (m = 1, 2, 3, \ldots)$$

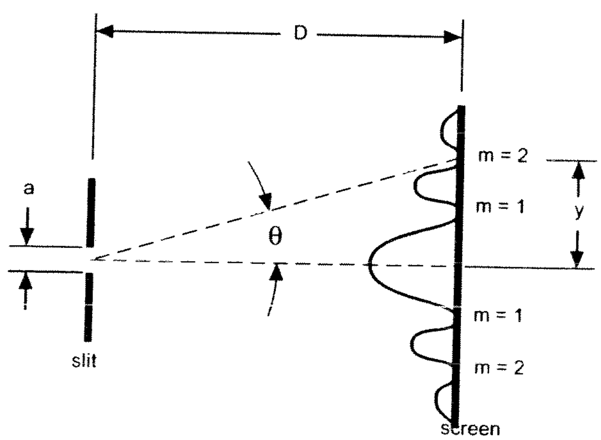


Figure 1.1: Single Slit Diffraction Pattern

Procedure

① Follow the setup procedure on page 2 of the manual using the 0.04 mm slit of the Single Slit Set.

② Measure the distance from the slit to the screen and record.

③ Turn off the room lights and mark the positions of the minima in the diffraction pattern on the projection surface.

④ Turn on the room lights and measure the distance between the first order (m = 1) marks and record this distance in Table 1.1. Also measure the distance between the second order (m = 2) marks and record in Table 1.1.

⑤ Make a sketch of the diffraction pattern to scale.

⑥ Change the slit width to 0.02 mm and 0.08 mm and make sketches to scale of each of these diffraction patterns.

Table 1.1: Data and Results for the 0.04 mm Single Slit

Slit-to-screen distance

(D) = ________________

	First Order (m=1)	Second Order (m=2)
Distance between side orders		
Distance from center to side (y)		
Calculated slit width		
% difference		

Analysis

① Divide the distances between side orders by two to get the distances from the center of the pattern to the first and second order minima. Record these values of y in Table 1.1.

② Using the average wavelength of the laser (670 nm for the Diode Laser), calculate the slit width twice, once using first order and once using second order. Record the results in Table 1.1.

③ Calculate the percent differences between the experimental slit widths and 0.04 mm. Record in Table 1.1.

Questions

① Does the distance between minima increase or decrease when the slit width is increased?

Experiment 2: Interference from a Double Slit

Materials required:

- optics bench[1]
- Diode Laser (OS-8528)
- Multiple Slit Set (OS-8529)
- white projection surface
- metric rule
- page 2 of the Slit Accessory manual

[1]From the Introductory or Advanced Optics System (OS-8500 or OS-9254A)

Purpose

The purpose of this experiment is to examine the diffraction and interference patterns formed by laser light passing through two slits and verify that the positions of the maxima in the interference pattern match the positions predicted by theory.

Theory

When light passes through two slits, the two light rays emerging from the slits interfere with each other and produce interference fringes. The angle to the maxima (bright fringes) in the interference pattern is given by

$$d\sin\theta = m\lambda \quad (m = 0, 1, 2, 3 \ldots)$$

where d is the slit separation, θ is the angle from the center of the pattern to the mth maximum, λ is the wavelength of the light, and m is the order (0 for the central maximum, 1 for the first side maximum, 2 for the second side maximum, . . . counting from the center out). See Figure 2.1.

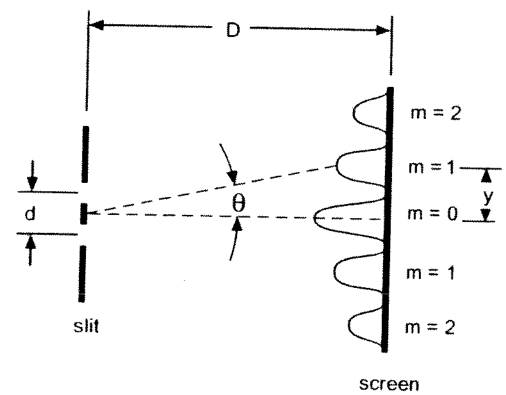


Figure 2.1: Interference Fringes

Since the angles are usually small, it can be assumed that

$$\sin\theta \cong \tan\theta$$

From trigonometry,

$$\tan\theta = \frac{y}{D}$$

where y is the distance on the screen from the center of the pattern to the mth maximum and D is the distance from the slits to the screen as shown in Figure 2.1. The interference equation can thus be solved for the slit separation:

$$d = \frac{m\lambda D}{y} \quad (m = 0, 1, 2, 3 \ldots)$$

While the interference fringes are created by the interference of the light coming from the two slits, there is also a diffraction effect occurring at each slit due to single slit diffraction, causing the envelope diagramed in Figure 2.2.

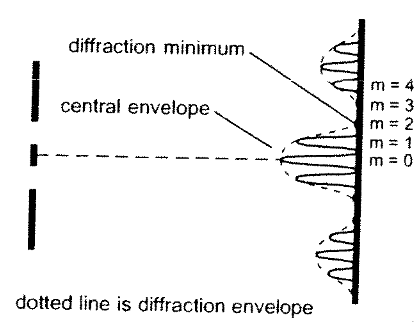


Figure 2.2: Single Slit Diffraction Envelope

Procedure

① Follow the setup procedure on page 2 of the manual using the Multiple Slit Set with the 0.04/0.25 mm (slit width/separation) double slit selected.

② Measure the distance from the slit to the screen and record.

③ Turn off the room lights and mark the positions of the maxima in the interference pattern on the screen.

④ Turn on the room lights and measure the distance between the first order (m = 1) marks and record this distance in Table 2.1. Also measure the distance between the second order (m = 2) marks and record in Table 2.1.

Slit-to-screen distance

(D) = ________________

Table 2.1: Data and Results for the 0.04/0.25 mm Double Slit

	First Order (m=1)	Second Order (m=2)
Distance between side orders		
Distance from center to side (y)		
Calculated slit separation		
% difference		

⑤ Make a sketch of the interference pattern to scale.

⑥ Change to a new double slit with the same slit width (0.04 mm) but different slit separation (0.50 mm) and make a sketch to scale of this new interference pattern.

⑦ Change to another double slit with a slit width of 0.08 mm and the original slit separation (0.25 mm) and make a sketch to scale of this new interference pattern.

Analysis

① Divide the distances between side orders by two to get the distances from the center of the pattern to the first and second order maxima. Record these values of y in Table 2.1.

② Using the average wavelength of the laser (670 nm for the Diode Laser), calculate the slit separation twice, once using first order and once using second order. Record the results in Table 2.1.

③ Calculate the percent differences between the experimental slit separation and 0.25 mm. Record in Table 2.1.

Questions

① Does the distance between maxima increase, decrease, or stay the same when the slit separation is increased?

② Does the distance between maxima increase, decrease, or stay the same when the slit width is increased?

③ Does the distance to the first minima in the diffraction envelope increase, decrease, or stay the same when the slit separation is increased?

④ Does the distance to the first minima in the diffraction envelope increase, decrease, or stay the same when the slit width is increased?

Experiment 3: Comparisons of Diffraction and Interference Patterns

Materials required:

- optics bench[1]
- Diode Laser (OS-8528)
- Single Slit and Multiple Slit Sets (OS-8529)
- white projection surface
- metric rule
- page 2 of the Slit Accessory manual

[1]From the Introductory or Advanced Optics System (OS-8500 or OS-9254A)

Purpose

The purpose of this experiment is to compare the diffraction and interference patterns formed by laser light passing through various combinations of slits.

Theory

When diffraction of light occurs as it passes through a slit, the angle to the minima in the diffraction pattern is given by

$$a \sin\theta = m\lambda \quad (m = 1, 2, 3 \ldots)$$

where a is the slit width, θ is the angle from the center of the pattern to the m[th] minimum, λ is the wavelength of the light, and m is the order (1 for the first minimum, 2 for the second minimum, . . . counting from the center out). See Figure 3.1.

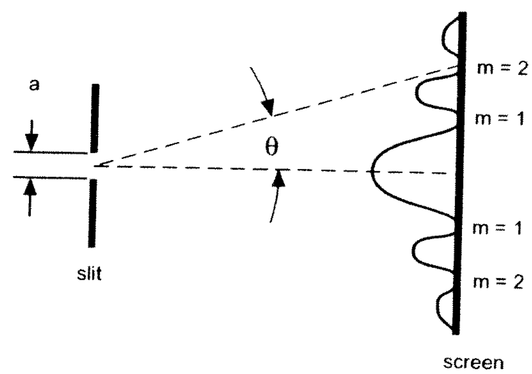


Figure 3.1: Single Slit Diffraction Pattern

When light passes through two slits, the two light rays emerging from the slits interfere with each other and produce interference fringes. The angle to the maxima (bright fringes) in the interference pattern is given by

$$d \sin\theta = m\lambda \quad (m = 0, 1, 2, 3 \ldots)$$

where d is the slit separation, θ is the angle from the center of the pattern to the m[th] maximum, λ is the wavelength of the light, and m is the order (0 for the central maximum, 1 for the first side maximum, 2 for the second side maximum, . . . counting from the center out). See Figure 3.2.

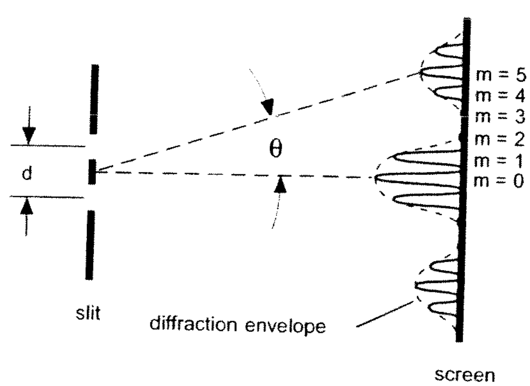


Figure 3.2: Interference Fringes

Procedure

① Follow the setup procedure on page 2 of the manual using the Multiple Slit Set with the single-double slit comparison selected.

② Sketch the two side-by-side patterns roughly to scale.

③ Rotate the slit disk to the next comparison set (2 double slits with the same slit width but different slit separations). Sketch the two side-by-side patterns roughly to scale.

④ Rotate the slit disk to the next comparison set (2 double slits with the same slit separation but different slit widths). Sketch the two side-by-side patterns roughly to scale.

⑤ Rotate the slit disk to the next comparison set (double slits/triple slits with the same slit separation and same slit widths). Sketch the two side-by-side patterns roughly to scale.

⑥ Replace the Multiple Slit Set with the Single Slit Set. Select the line/slit comparison. Sketch the two side-by-side patterns roughly to scale.

⑦ Select the dot pattern, and sketch the resulting diffraction pattern roughly to scale.

⑧ Select the hole pattern, and sketch the resulting diffraction pattern roughly to scale.

Questions

① What are the similarities and differences between the single slit and the double slit?

② How does the double slit pattern change when the slit separation is increased?

③ How does the double slit pattern change when the slit width is increased?

④ What differences are there between a double slit pattern and a triple slit pattern?

Technical Support

Feedback

If you have any comments about the product or manual, please let us know. If you have any suggestions on alternate experiments or find a problem in the manual, please tell us. PASCO appreciates any customer feedback. Your input helps us evaluate and improve our product.

To Reach PASCO

For technical support, call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

fax: (916) 786-3292

e-mail: techsupp@pasco.com

web: www.pasco.com

Contacting Technical Support

Before you call the PASCO Technical Support staff, it would be helpful to prepare the following information:

➤ If your problem is with the PASCO apparatus, note:

- Title and model number (usually listed on the label);
- Approximate age of apparatus;
- A detailed description of the problem/sequence of events (in case you can't call PASCO right away, you won't lose valuable data);
- If possible, have the apparatus within reach when calling to facilitate description of individual parts.

➤ If your problem relates to the instruction manual, note:

- Part number and revision (listed by month and year on the front cover);
- Have the manual at hand to discuss your questions.