Chapter 24 INTERFERENCE

Over the past few chapters we have been comparing, and contrasting, the behavior of water waves with that of light. We found that water waves reflect and refract in the same way as does light. In the last chapter we also observed that these water waves BEND around edges of barriers - a phenomenon called diffraction. Careful examination of the behavior of light shows that light also exhibits the effect of diffraction, and this led us to deduce that the wavelength of light must be very small.

In this chapter we will look at another effect found in water waves - interference. This will lead us in the following chapter to see whether we can also detect the phenomenon of interference of light.

At this point you might be inclined to ask, where is all this seemingly endless comparison between water waves and light leading? The answer to this question has three parts.

1. It is leading to a complete explanation of the character of light.
2. It is providing us (whether we realize it or not) with an understanding of all aspects of light behavior.
3. Since waves are important and interesting in themselves, it is providing us with important insight into wave behavior.

PERFORMANCE OBJECTIVES

After completing this chapter, you should be able to:

1. Demonstrate a two-point interference pattern in a ripple tank when:
   a. the sources are in phase,
   b. the sources are out of phase by 1/2 (180 degrees).

2. Predict the resulting two-point source interference pattern that one gets when:
   a. the sources are in phase,
   b. the sources are out of phase by 1/2.

3. Explain how the following changes will affect the interference pattern provided by two-point sources:
   a. a change in frequency,
   b. a change in source separation,
   c. a change in frequency of one source relative to the other.

4. Mathematically predict the number of nodal lines when given the source separation as a function of the wavelength.

5. Calculate mathematically the wavelength from an interference pattern produced by two-point sources in phase using the following formula:

$$\lambda = \frac{\Delta d}{n - 1/2} \qquad \lambda = \frac{d \sin\theta}{n - 1/2} \qquad \lambda = \frac{d\, x_n/L}{n - 1/2}$$

6. Modify the above equations to account for two-point sources being out-of-phase.

1. Read: Section 24-1 Interference on a Spring page 487

2. What kind of interference can you demonstrate using the slinky? Obtain a slinky and:

   a. Send two pulses from one end. When? Where? How do they interfere?

   b. Vary the amplitude and length of the pulse. Results?

   c. Send two pulses from the same side, one from each end.
      Send two pulses, from opposite sides, one from each end.

      1. Did the pulses start at the same time?
      2. How can you tell?
      3. What two factors determine where they will meet?

3. Problems: page 487: #1 #2
   499: #12

4. Experiment: INTERFERENCE FROM TWO POINT SOURCES (Directions provided.)

   a. A written summary using the questions as a guide is to be presented to your instructor for evaluation.

5. Read: Section 24-2 Interference From Two Point Sources page 488
   24-3 The Shape of Nodal Lines page 491

   a. How are the nodal lines numbered? The anti-nodal lines?

   b. Optional...View the following Film Loops:

      RT-11 Superposition of Pulses
      RT-12 Interference of Waves

6. Problems: page 491: #3 #4
   492: #5 #6 #7
   499: #15 #17

7. Use the enclosed work sheet which shows the crests (thicker lines) and troughs (thinner lines) with the distance (d) between sources equal to 5 wavelengths.

   a. Are the sources in phase? How do you know?

   b. Locate, draw and number the nodal lines in the 1st quadrant. How many are there?

   c. What exists on a line perpendicular to and bisecting the line between the two sources?

   d. Locate a point on a line perpendicular to and bisecting the line between the two sources and show the direction of motion by vector addition of individual velocities of each pulse.

   e. Locate and draw the nodal lines in the other three quadrants. Notice the symmetrical pattern that exists.

f. For a few points on each nodal line in the 1st quadrant, determine the path difference " Δd" between that point and the two sources in units of wavelength.

g. Develop a mathematical expression which equates the path difference as a function of the wavelength " λ " and the nodal line "n".

Note..." d" represents the path difference between a point in the pattern to one point source and that point to the other point source while "d" represents the distance between the two point sources.

8. In Item 7, it is hoped that you found that $\Delta d = (n - 1/2)\lambda$. This equation is good only when:

a. the two point sources are not too close together, and

b. the point on the nodal line (to which one measures) is not too far from the two point sources.

c. Solving for the wavelength, one gets: λ = ______________.

Knowing that the wavelength for light is very small, what limitations might one place on the above formula when:

d. you work far, far from the two point sources, and/or

e. when the sources are very close together?

9. Read: Section 24-4 Wavelength, Source Separation, and Angles p 493

10. Satisfy that the following two equations are correct based on the assumptions given in Section 24-4 of the text.

$$\lambda = \frac{d \sin \theta}{n - 1/2} \qquad \lambda = \frac{d \; x_n/L}{n - 1/2}$$

What are the two assumptions?

11. One of the problems you may face is that of predicting the number of nodal lines that exist for a given situation where "d" and "λ " are known. Show that the equation $\lambda = d \sin \theta / (n - 1/2)$ can be used to predict the number of nodal lines.

Hint...What value will we use for θ?

12. Problems: page 495: #8
500: #19 #20 #21 #22

13. Use the apparatus of the last experiment to generate an interference pattern of two point sources in phase, or use Film Loop RT-12 to project an interference pattern on a piece of paper to:

a. locate two points on each of two different numbered nodal lines (in the 1st quadrant), one close to and one far from the two point sources, and

b. measure the wavelength of the actual wave.

c. Determine the wavelength using the following equations:

$$\lambda = \frac{\Delta d}{n - 1/2} \qquad \lambda = \frac{d \sin \theta}{n - 1/2} \qquad \lambda = \frac{d\, x_n/L}{n - 1/2}$$

d. Compare the calculated wavelengths to the measured value. Report your findings to your instructor.

14. Read: Section 24-5 Phase page 495

a. What is: t ____________? T ____________? p ____________?

b. The phase delay "p" equals _______. (mathematical formula)

c. How is "t" related to "T"?

d. Why must "p" be bounded by zero and 1/2 rather than by zero and 1?

e. If S_1 falls behind S_2, which way do the nodal lines bend?

15. Using the ripple tank, demonstrate activities suggested in Experiment 41 INTERFERENCE AND PHASE page 90. No write-up is necessary.

16. Optional...Film Loop RT-13: Effect of Phase Difference Between Sources

17. Summary...A simple alteration to the previous formulae can be made which will allow for phase delay if there is one. To make the alteration, replace (n - 1/2) with (p + n - 1/2). The altered equations will then be useful whether or not the sources are in phase.

18. Problems: page 498: #9 #10
500: #24 #25 #26 #27 #28

19. Read: Section 24-6 Summary and Conclusions page 498

20. What would the interference pattern look like if it were made by two sources that were not in phase?

a. Place two generators in a ripple tank, each with one point source on it.

b. Vary the frequency of one relative to the other and observe the results.

21. You have now finished experimenting with the ripple tank. Empty it, wipe it clean and dismantle it. Then see that it is put away.

22. Complete enclosed Written Exercise titled INTERFERENCE and then have it evaluated.

2. (c)(3) path difference, phase difference

3. (1) (12) S.A.B.
   (2) A distance of 1 wavelength from the wall.

6. (3) Double Crest-A, Double Trough-C, Nodal Point-B
   (4) (a) greater in Fig. 24-9 (b) more nodal lines in Fig. 24-6
   (5) Second Nodal Line
   (6) On which nodal line the point lies.
   (7) (17) S.A.B.
   (15) See instructor for a demonstration using measuring tapes.

7. (a) yes-crest of one source are same distance from their source as a corresponding crest is from its source
   (b) 5 (c) anti-nodal point (constructive interference)
   (d) Have instructor check.
   (f) $n = 1$, path difference = 1/2 wavelength
   $n = 2$, path difference = 3/2 wavelength
   $n = 3$, path difference = 5/2 wavelength and so forth
   (g) $\Delta d = (n-1/2)\lambda$

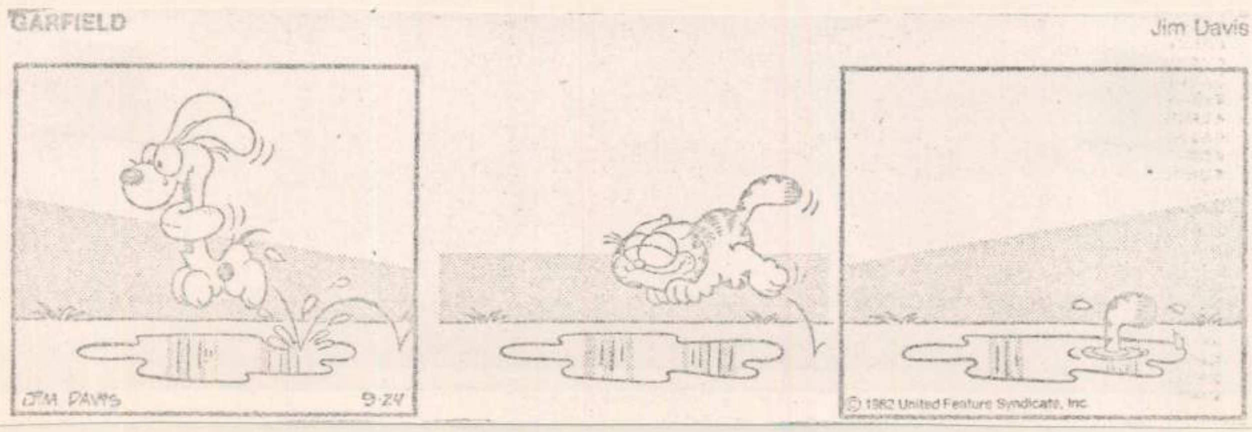
8. (c) $\lambda = \Delta d/(n-1/2)$
   (d) The path difference Δd could be smaller than the accuracy of the value when measured.

10. d is small, x_n is small

12. (8) When the wavelength is greater than 2d.
   (19) S.A.B.
   (20) (a) 0.24 (b) 2.0 cm, 2.9 cm
   (22) β = 23.6 deg. γ = 36.9 deg., β = 29.3 deg. γ = 30.7 deg.

14. (a) t = time delay T = period p = phase delay
   (b) $p = t/T$
   (c) $t <= T$
   (d) One cannot be ahead of the other by more than 1/2 T.
   (e) towards S_1

18. (9) 0.36
   (10) yes
   (23) (a) 1/5 (b) 2 km/min (c) 1.6 km/min
   (24) (25) (26) (27) S.A.B.
   (28) (a) 1/2 (b) pi/2 radians



INTERFERENCE FROM TWO POINT SOURCES

When two or more waves pass through the same point at the same time, they interfer with one another. The magnitude of the disturbance may be predicted by application of the principle of superposition. That is, the resultant is the algebraic sum of the disturbances due to the individual waves. Sometimes, a consistant interference pattern is produced. Standing waves are one example of such a pattern. Two adjacent point sources in a ripple tank product an interference pattern which has important physical applications.

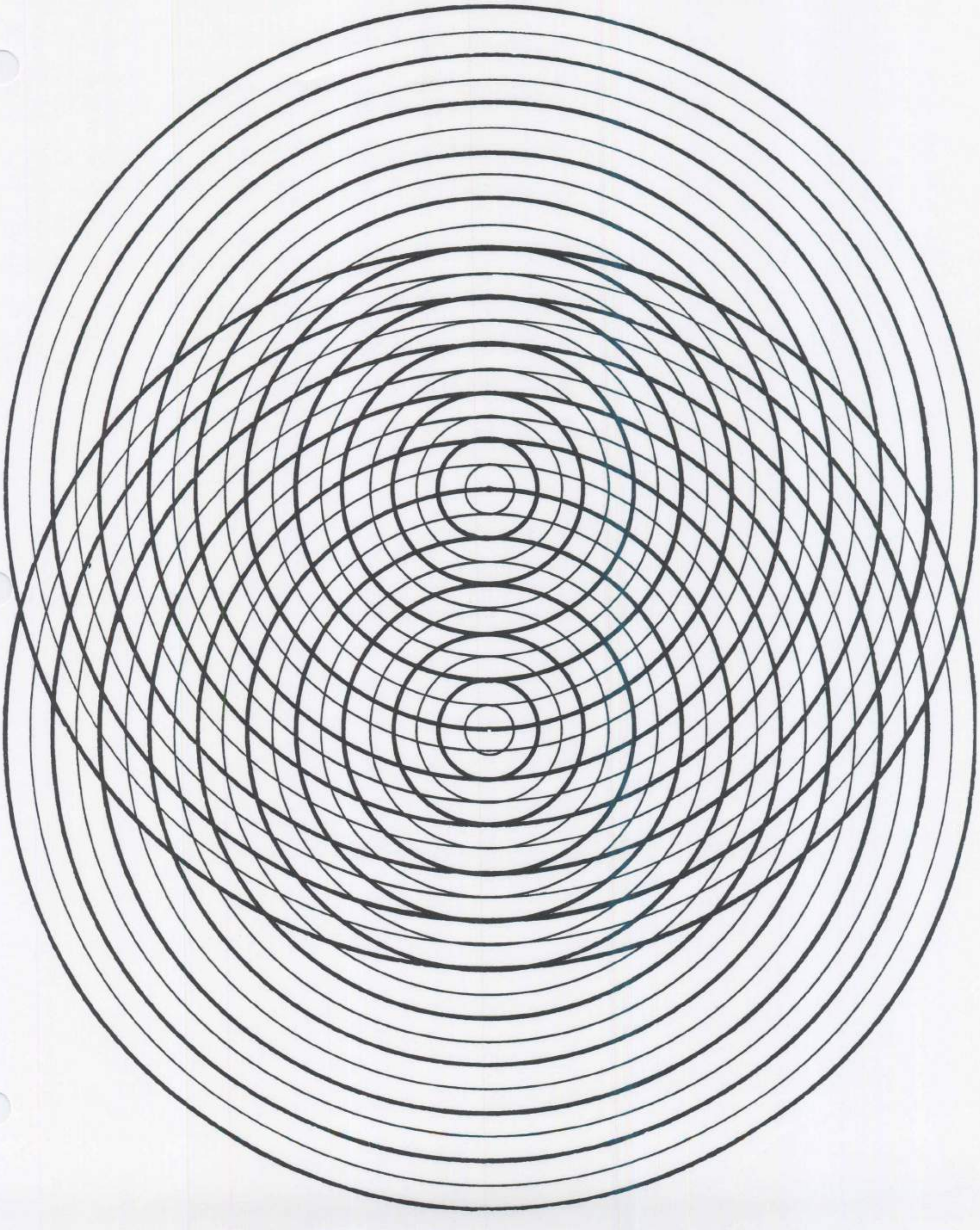
Set up the ripple tank and place two point sources about 5 cm apart on the wave generator. Adjust the wood or plastic dowels until both clothes pins are moving up and down at the same time. Have your instructor check the pattern when you think you have the two point sources vibrating in phase.

Describe the resulting pattern. The points where the waves from the two point sources cancel (points of little or practically no disturbance) are called 'nodes'. Lines formed by joining adjacent nodes are called nodal lines. Points of maximum disturbance are called antinodes.

Increase the frequency of the generator. What happens to the pattern of nodal and antinodal lines? Does the number of nodal lines increase or decrease?

A second area of investigation will be the distance between the two point sources. Ideally the distance between the two point sources should be changed without stopping the generator to assure that the frequency is kept as nearly constant as possible. Since we cannot do that, shut off the generator using the key. Adjust the distance between the two sources, turn on the generator and observe the pattern. How does changing the distance affect the pattern? Make special note as to whether you think the generator remained at the same frequency both before and after the adjustment.

Report your findings to your instructor and ask to see the transparencies that can assist you in understanding of how the distance between two point sources affects the number of nodal lines.



Chapter 24 Written Exercise Interference

1. A point on the third line is found to be 35.0 cm from one source and 42.7 cm from the other. (a) What is the path difference? (b) What is the wave length? (c) If the sources are 9.3 cm apart, what is the interference angle of this line? (d) How many nodal lines are there?

   a. ______________

   b. ______________

   c. ______________

   d. ______________

2. Two point sources (in phase) in a ripple tank are 9.0 cm apart, and vibrate to produce a 3.4 cm wave. How many nodal lines are produced?

   ____

Empirical data has been gathered to show that the formula $v = 332 + 0.6T$ (in meters per second), is valid for the velocity of sound through the atmosphere for the range of temperatures we ordinarily experience. [v = velocity; T = temperature difference between $0^{\circ}C$ and the temperature at which you wish to calculate the velocity of sound.]

Expensive experimentation has shown that sound exhibits behaviors that are similar to the wave phenomenon we have observed in the ripple tank.

3. Using the above formula; calculate the velocity of sound at $19^{\circ}C$.

   ____

4. What is the wavelength of the sound from the middle "C" string of a piano under the conditions stated in problem three. (f = 256 cycles/sec)

   ____

5. When the temperature is $42^{\circ}C$, the echo of a ship's horn returns by way of a cliff to the ship in 5.7 seconds. How far is the ship from the cliff?

   ____

6. Two loudspeakers are located 9.3 meters apart at the front of an auditorium. A test record on which was recorded a certain sound of constant frequency is played through the above speaker system. An observer hears the sound loud and clear when standing anywhere in the center aisle, but hears "dead spots" in the auditorium as he moves about from place to place. He attaches a rope of 28 meters long to a point midway between the speakers. He then moves in an arc and discovers the first dead spot 3.1 meters to the right of the center aisle. What is the wave length of the sound reproduced by the test record?

____

7. How far apart must two point sources be placed in a ripple tank in order for the second nodal line to be at 20° if the wave travels at 24 cm/sec and the frequency is 13/sec?

____

8. A series of periodic transverse waves, frequency of 14 cycles/sec, travels along a string. The distance between a crest and either adjacent trough is 3.4 m.
(a) What is the wavelength?
(b) What is the speed of the wave motion?

a. _______________

b. _______________

9. A "phase delay" is indicated. What does it mean to you?

Chapter ~~7~~ 24 Test ~~Interference~~ Written Exercise

1. A point on the third line is found to be 35.0 cm from one source and 42.7 cm from the other. (a) What is the path difference? (b) What is the wave length? (c) If the sources are 9.3 cm apart, what is the interference angle of this line? (d) How many nodal lines are there?

a. 7.7 cm

b. 3.08 cm

c. 55.9°

d. 3

$n = 3$ (a) $\Delta d = 42.7\,cm - 35.0\,cm =$

(b) $\lambda = \frac{\Delta d}{n - 1/2} = \frac{7.7\,cm}{2.5} = 3.08\,m$

$d = 9.3\,cm$

(c) $\lambda = \frac{d \sin\theta}{n - 1/2} \Rightarrow \sin\theta = \frac{\lambda}{d}(n - 1/2)$

$= \frac{3.08\,cm}{9.3\,cm}(2.5)$

(d) $0 \le \sin\theta \le 1$

$\frac{\lambda}{d}(n - 1/2) = 1$ (at max)

$n - 1/2 = \frac{d}{\lambda}$

$n = \frac{d}{\lambda} + \frac{1}{2}$

$= \frac{9.3}{3.08} + .5 = 3.52$

2. Two point sources (in phase) in a ripple tank are 9.0 cm apart, and vibrate to produce a 3.4 cm wave. How many nodal lines are produced?

3

$n = \frac{d}{\lambda} + \frac{1}{2}$

$\frac{9.0\,cm}{3.4\,cm} + \frac{1}{2}$ $= 2.64$

Empirical data has been gathered to show that the formula v = 332 + 0.6T (in meters per second), is valid for the velocity of sound through the atmosphere for the range of temperatures we ordinarily experience. [v = velocity; T = temperature difference between 0°C and the temperature at which you wish to calculate the velocity of sound.]

Expensive experimentation has shown that sound exhibits behaviors that are similar to the wave phenomenon we have observed in the ripple tank.

3. Using the above formula; calculate the velocity of sound at 19°C.

343.4 M/sec

$v = 332\,\frac{M}{S} + \frac{0.6M}{S}(19$

$+ 11.4$

4. What is the wavelength of the sound from the middle "C" string of a piano under the conditions stated in problem three. (f = 256 cycles/sec)

1.34 M

$v = f\lambda$ $\quad \lambda = \frac{v}{f} = \frac{343.4}{256}\frac{M}{S}$

5. When the temperature is 42°C, the echo of a ship's horn returns by way of a cliff to the ship in 5.7 seconds. How far is the ship from the cliff?

1018 M

$d = ?$

$t = 5.7\,sec$

$v = 357.2\,\frac{M}{S}$

$d = vt$

$v = 332\,\frac{M}{S} + (0.6\,\frac{M}{S})\,42$

$+ 25.2$

$d = 357.2\,\frac{M}{S} \times 5.7\,sec$

$= 2036\,M$

6. Two loudspeakers are located 9.3 meters apart at the front of an auditorium. A test record on which was recorded a certain sound of constant frequency is played through the above speaker system. An observer hears the sound loud and clear when standing anywhere in the center aisle, but hears "dead spots" in the auditorium as he moves about from place to place. He attaches a rope of 28 meters long to a point midway between the speakers. He then moves in an arc and discovers the first dead spot 3.1 meters to the right of the center aisle. What is the wave length of the sound reproduced by the test record?

2.06 M

$d = 9.3\,M$

$L = 28\,M$

$x_1 = 3.1\,M$

$\lambda =$

$\lambda = \frac{d\,x_n}{L(n-\frac{1}{2})} = \frac{9.3\,M \cdot 3.1\,M}{28\,M \cdot 0.5} = 2.06\,M$

7. How far apart must two point sources be placed in a ripple tank in order for the second nodal line to be at 20° if the wave travels at 24 cm/sec and the frequency is 13/sec?

8.10 CM

$\lambda = \frac{v}{f} \quad \frac{24\,cm/s}{13/s} = 1.85$

$d = ?$

$n = 2$

$\theta = 20°$

$v = 24\,\frac{cm}{sec}$

$f = 13/sec$

$\lambda = \frac{v}{f}$

$\lambda = \frac{d \sin\theta}{n-\frac{1}{2}}$

$d = \frac{\lambda(n-\frac{1}{2})}{\sin\theta}$

$d = \frac{v}{f}\frac{(n-\frac{1}{2})}{\sin\theta}$

$24\,\frac{cm}{sec} \times \frac{1.5\,sec}{13 \cdot \sin 20°}$

8. A series of periodic transverse waves, frequency of 14 cycles/sec, travels along a string. The distance between a crest and either adjacent trough is 3.4 m.
(a) What is the wavelength?
(b) What is the speed of the wave motion?

a. 6.8 M

b. 95.2 M/s

$f = 14\,\frac{1}{sec}$

$\frac{1}{2}\lambda = 3.4\,M$

$v = f\lambda = \frac{14}{sec}\,6.8\,M$

9. A "phase delay" is indicated. What does it mean to you?

$P = \frac{t}{T}$ → RATIO

TEST CHAPTER 24 NAME ____________________________

1. Attached to this quiz is a representation of an interference pattern produced by two point sources of waves.

   A. Carefully draw and label the following:
      a. the central maximum
      b. the third nodal line
      c. the locus (i.e. set) of points that are one wavelength further from S1 than from S2.

   B. Calculate the angle to the third maximum line using $d \sin \theta$ for the path difference.

   C. Using the attached diagram, pick a point on the third maximum line and draw a line connecting this point with the point midway between the sources. Measure the angle between this line and the central maximum. If all drawings, measurements, and calculation are perfect, do you expect this angle to be equal to the answer in (B) above. If not which do you expect to be larger and why?

2. When we were analyzing two point interference patterns, why did we develop two different equations for path difference?

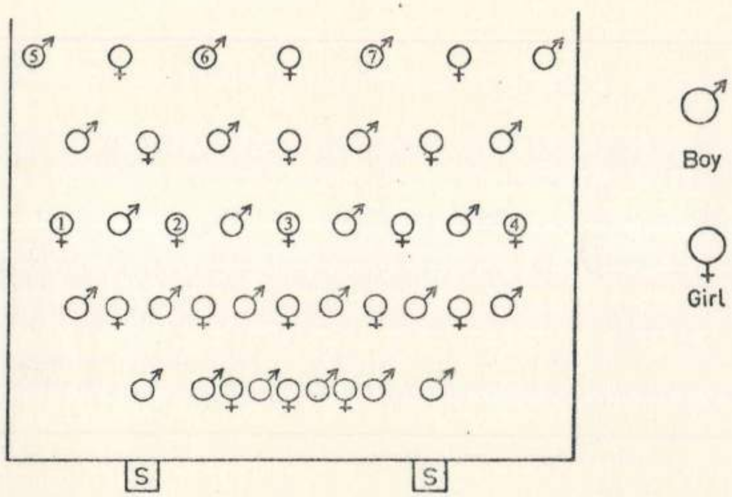
3. Describe two independent ways you could decrease the number of nodal lines that are present in a two point interference pattern.

4. What would be the appearance of the interference pattern of two point sources if the phase between the sources was constantly changing in a rapid and random manner?

1a. ___ 1b. ___ 1c. ___ 2. ___ 3. ___ 4. ___ 5. ___ 6. ___ 7. ___

Name ______________________________

1 a. On a day when there is no wind, a loudspeaker S is placed at each goalpost at one end of a football field. The loudspeakers are in phase and are emitting sounds of the same constant frequency and intensity. The boys in a class are asked to find positions on the field where the sound is faintest and the girls to find positions where the sound is loudest. The positions taken are shown in the diagram below.



Which one of the following changes would result in the students standing closer together?

(A) Increasing the wavelength of the note emitted

(B) Moving the loudspeakers closer together

(C) Increasing the frequency of the note emitted

(D) Choosing a day when the air temperature is much higher

(E) Putting the loudspeakers out of phase

1 b. Which girl is at a point one wavelength further from one loudspeaker than from the other?

(A) 1	(C) 3	(E) None of the above
(B) 2	(D) 4	

1 c. Which student is at a position with best satisfies the conditions $\frac{X}{L} = \frac{3\lambda}{2d}$?

X = the distance from the student to the right bisector of the line joining the loudspeakers

L = the distance of the student from the midpoint between the speakers

λ = the wavelength of the sound from the speakers

and d = the distance between the speakers

(A) 2	(C) 5	(E) 7
(B) 4	(D) 6	

2. An interference pattern is produced by two point sources vibrating in phase in a ripple tank. If the frequency of the two point sources increases, the pattern

(A) has fewer nodal lines

(B) has more nodal lines

(C) remains the same

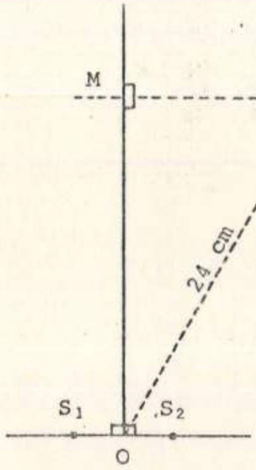
(D) spreads out farther into the ripple tank

(E) spreads out less into the ripple tank

3. Two point-sources in a ripple tank vibrate in phase at a frequency of 12 Hz to produce waves having a wavelength 0.024 m. The difference in path-length from the two point-sources to a point on the second nodal line is

(A) 0.6 cm	(C) 2.4 cm	(E) 4.8 cm
(B) 1.2 cm	(D) 3.6 cm	

4. S_1 and S_2 are two point sources situated 6 cm apart, vibrating in phase, and producing waves having a wavelength of $\frac{5}{4}$ cm. (Diagram not drawn to scale.)



If Q is a point on the second nodal line, 24 cm away from O, then MQ is approximately

(A) 2.5 cm
(B) 5 cm
(C) 7.5 cm
(D) 10 cm
(E) 15 cm

5. The distance between successive nodes in a standing wave pattern is

(A) 1/4 λ
(B) 1/2 λ
(C) 3/4 λ
(D) 1 λ
(E) 2 λ

6. A nodal line pattern is produced by two point sources vibrating in phase in a ripple tank. A point P is selected on the second nodal line so that it is 37 cm from one source and 28 cm from the other source. The wavelength of the waves in centimetres is

(A) 18
(B) 13.5
(C) 9.0
(D) 6.0
(E) 4.5

7. S_1 and S_2 are two point sources situated 6 cm apart, vibrating in phase, and producing waves having a wavelength of $\frac{5}{4}$ cm. (Diagram not drawn to scale.)

If P is a point on the first nodal line, then $PS_1 - PS_2$ will be equal to

(A) $\frac{5}{48}$ cm
(B) $\frac{5}{24}$ cm
(C) $\frac{5}{8}$ cm
(D) $\frac{5}{4}$ cm
(E) $\frac{15}{8}$ cm

8. Two periodic point sources vibrating in phase produce an interference pattern on a water surface.

The path difference between the two point sources and a point on the n^{th} nodal line is

(A) $n\lambda$
(B) $(n - 1)\lambda$
(C) $(n + 1)\lambda$
(D) $(n + \frac{1}{2})\lambda$
(E) $(n - \frac{1}{2})\lambda$

notes

Ghosts in the classroom

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While a TV "ghost" may be aggravating to a casual viewer, it is an opportunity for a physics teacher to create a student project that is unique to the local conditions. The phenomenon has been used to measure the speed of light,[1] but the objective of this project is to locate the building or object causing the ghost (as was also the case in Ref. 2). The project involves the propagation and reflection of radio waves, the use of a TV set as a timer in the microsecond range, and ingenuity from the students.

TV "ghosts" are faint images displaced from the normal image on the screen. They are due to a reflected signal arriving at the receiver slightly later than the signal coming directly from the transmitter. The ghost signal exists because it is a reflection from some nearby structure. Since it does not travel along the shortest path from the transmitter, it arrives later. The signal strength of the ghost will usually be less than that of the direct signal because the reflector is imperfect and will tend to disperse the beam.

Since 525 lines are formed on the TV screen in 1/30 sec (in the U.S.), it would seem that each line is traced in 63.49 μsec. But actually, only 53.33 μsec are used. During the remaining 10.16 μsec the electron beam is off and a synchronization signal is received.[3] So if the length of the line on a TV picture tube is L (including overscan[1]), and the ghost is ΔL from the normal image, then the time delay of the ghost is 53.33 $\Delta L/L$ μsec. With the speed of light in air being about 2.997×10^8 m/sec, the extra distance traveled by the ghost signal is 15980 $\Delta L/L$ m or 9.931 $\Delta L/L$ miles. For example, a ghost that is 5.0 cm from the normal image on a TV tube that is 40-cm wide must have traveled 2.0×10^3 m or 1.2 miles farther than the direct signal.

A complication now arises because knowing the extra distance is not sufficient to locate the reflector uniquely. It could be anywhere on an ellipse whose foci are the transmitting and receiving antennae (Fig. 1). The string and pin construction of an ellipse shows this to be true. The string's length $(s_1 + s_2)$ is greater than the distance D between the pins at the foci by 9.931 $\Delta L/L$ miles. However, since a reflected beam will be weak, only the positions on the ellipse within a very few miles of the receiver need be considered as likely ghost sources. The reflection is also more likely to come from a structure rising above the general terrain.

By constructing the appropriate ellipse on an accurate, detailed map, the students can look for local structures that lie on (or very near) the ellipse. To construct the ellipse, the following information is needed: (a) the straight-line distance D from the transmitter to the receiver, (b) the direction to the transmitter from the TV's location, and (c) the extra distance traveled by the reflected signal. Various maps can provide the numbers for (a) and (b). The most accurate are those of the U.S. Geological Survey.[4] They are also available on such small scales that the vicinity of a city is clearly presented, including broadcasting towers, water towers, and even some individual buildings. With these inexpensive maps, it is possible to pinpoint likely sources of ghosts.

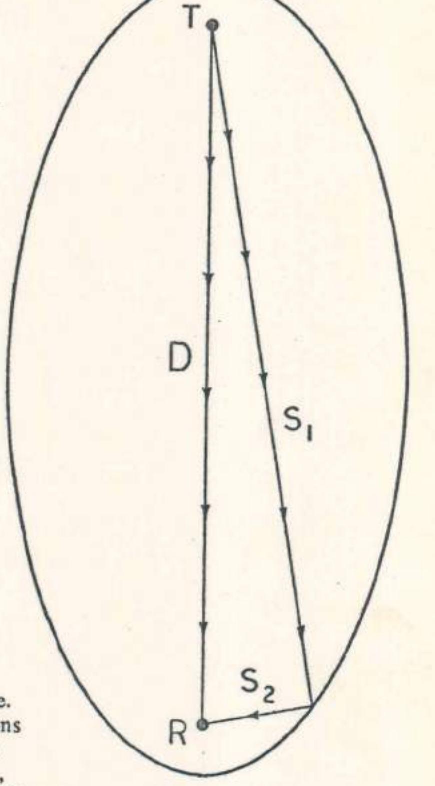

Fig. 1. The transmitter T and the receiver R are at the foci of an ellipse. All ghosts due to reflections from points on the ellipse travel the distance $s_1 + s_2$, which is greater than the distance D followed by the direct signal.

The semi-axes a and b of the ellipse $(x/a)^2 + (y/b)^2 = 1$ can be deduced, using Fig. 1. The geometry of the ellipse gives

$$9.931\Delta L/L = (s_1 + s_2) - D = 2b - D \quad (1)$$

which can be solved for b to get

$$b = (9.931\Delta L/L + D)/2 \quad (2)$$

But since $D = 2\sqrt{b^2 - a^2}$, it follows that

$$a = \sqrt{b^2 - D^2/4} \quad (3)$$

After using Eqs. (2) and (3) to get a and b, the ellipse can be drawn by selecting values of y and calculating

$$x = \pm a\sqrt{1 - (y/b)^2} \quad (4)$$

A pocket calculator can make this less painful, and it is an excellent application for a programmable calculator.

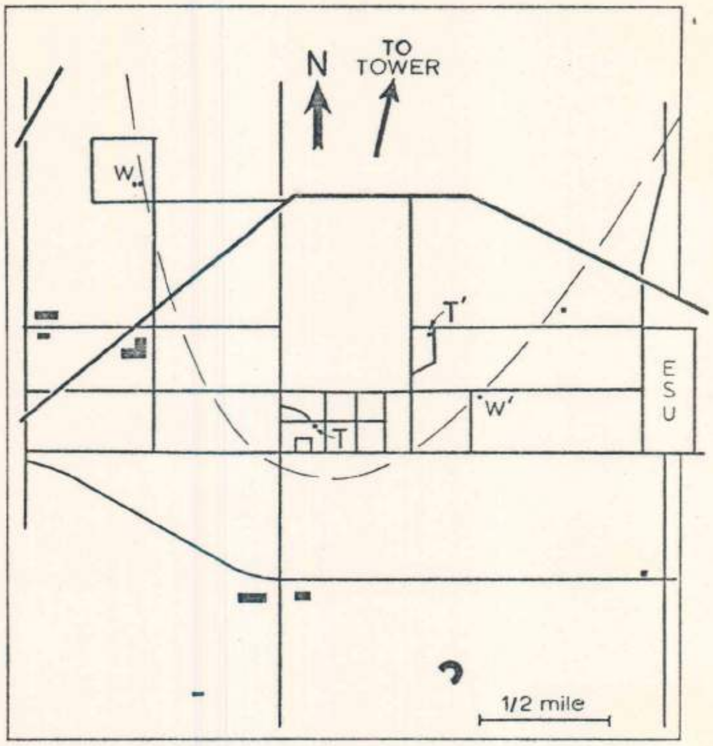

Fig. 2. A portion of Emporia is copied from a USGS map. The author's TV is at position T. A portion of the ellipse is shown (dashed line) which corresponds to the ghost displaced by 5/8 in. out of a total span of 18 in. Some of the larger structures nearby are indicated, including two water storage tanks W and a small water tower W′. A second TV set used is at the position shown by T′.

As an example, while viewing the VHF channel 13 from Topeka, my set can show a ghost very clearly. The line length L is about 18 in. (allowing 10% for overscan beyond the visible borders), and the ghost is displaced by $\Delta L = 5/8$ in. Thus the extra distance is about 0.34 mile. A USGS map indicates that $D = 42$ miles, with an angle from Emporia to the transmission tower of 12° E of N. (I had to position the relatively new tower on the map by measuring its position with my car relative to road intersections surrounding the tower.) So for this ghost, $b = 21$ miles and $a = 2.7$ miles.

I drew the ellipse on tracing paper to the scale of the USGS map showing Emporia in the largest detail. The tracing paper was then superimposed on the map, keeping in mind that the long axis of the ellipse must be 12° E of N (Fig. 2). Two likely structures were found on the ellipse: large water storage tanks W on high ground (Kansas standards imposed here), and a smaller but closer water tower W′.

To help decide between these two possibilities, another TV set at a friend's house (T′ on Fig. 2) was similarly used. For some antenna positions, a ghost was seen whose ellipse very nearly passed through W′ while no ghosts came close to W. It thus seems that the nearest water tower W′ is the most likely source of the ghost.

My thanks to Garnett Hill for providing this second ghost.

References

1. J. M. Reynolds, Phys. Teach. 15, 56 (1977).
2. D. T. Cropp, Phys. Teach. 15, 196 (1977).
3. Milton Kiver and Milton Kaufman, *Television Simplified* (Van Nostrand, New York, 1973), 7th ed., p. 22.
4. Order maps of areas east of the Mississippi from Distribution Section, U. S. Geological Survey, 1200 South Eads Street, Arlington, Virginia 22202. For maps of areas west of the Mississippi, order from Distribution Section, U. S. Geological Survey, Federal Center, Denver, Colorado 80225. To decide which maps to order, first ask for an "Index to Topographical Maps of (give your State)." This index will show the maps available, their sizes and prices. Currently, the prices are about $1.25 per map.

The Rydberg constant — a hand-calculator exercise

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In general, electronic calculators are convenient rather than essential but for many calculations in spectroscopy they cannot really be dispensed with if full use is to be made of accurate data. For example, when Niels Bohr developed his theory of the H atom he showed that in the already established expression for the wavenumber values of spectral lines,

$$\bar{\nu} = R\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right] \tag{1}$$

where $\bar{\nu}$ is $1/\lambda$, the reciprocal of the wavelength, the Rydberg constant R could be expressed as

$$R = \frac{me^4}{8\ \epsilon_0^2\ c\ h^3} \tag{2}$$

where

m is the electron mass
e the electron charge
ϵ_0 the permittivity of space
c the velocity of light and
h Planck's constant

and hence was calculable from a knowledge of the natural constants. It is of interest to test this using modern measurements (see table). The experimentally derived value of

OBJECTIVE TEST: Ch. 17
"Interference"

PSSC Physics
Name________________________

1. a) Define interference:

   b) Offer 3 examples--3 different types of waves producing interference (answer what they are and what they do)
      1.

      2.

      3.

2. a) Define "standing wave":

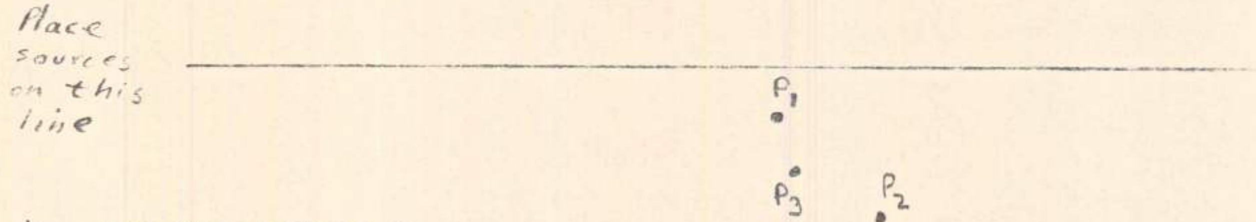
   b) Offer 3 examples--3 different types of waves producing this effect (Name the medium and describe what happens when the standing waves are in it):
      1.

      2.

      3.

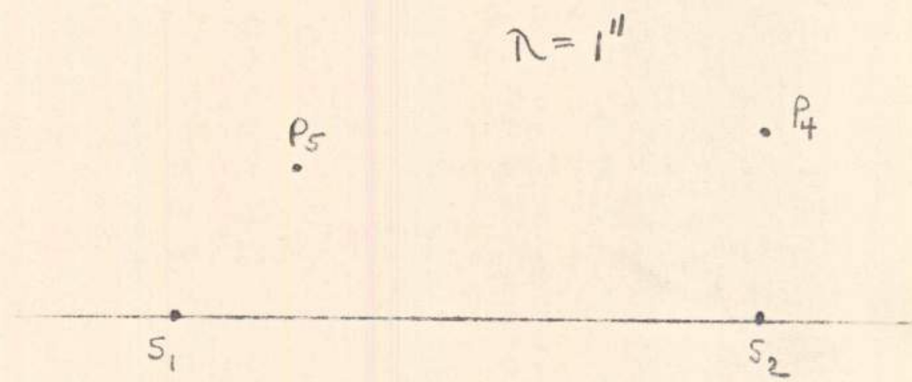
3. a) The source separation is 4" and the wavelength is 1". Construct and locate accurately (1) all major(xxxxxxxxxx noc points; (2) the complete family of nodal lines.

Place sources on this line ____



4. Are the points P_n nodal points or not?

P_1: ________
P_2: ________
P_3: ________
P_4: ________
P_5: ________



5. The wavelength produced by 2 sources is 1" and their separation is 3". Compute the entire set of angles for the first 3 nodal lines (to the left and to the right). Use the table supplied.

Ans's: ________
____
____
____
____
____

6. a) Define "phase delay":

b) Two sources generate waves at 1/40 sec intervals, only one source hits the water 1/60 sec after the other one all the time. Compute the phase delay of the 2nd source.

Ans: ________

7. a) Sketch below the pattern freehand, of nodal lines from 2 sources when they are in phase:

b) Sketch below the pa[t]
freehand, of nodal [l]
from 2 sources when
are 180^o out of pha[s]

c) Describe, in your own words, how the pattern would be aff[e]
if they were alternately switched "in phase" and "out of phase" rapidly:

8. Describe completely, under what conditions you can have 2 sour[ces]
generating waves in phase, and yet produce no nodal lines:

9. Two point sources are generating waves, with the same waveleng[th]
of 1 cm and they are placed in the ripple tank a distance of 5
apart.

a) If the sources are in phase, what angle Θ does the straigh[t]
part of the first nodal line make with the central line?

Ans:______

b) If the sources have a phase delay $p = \frac{1}{2}$, what is θ ?

Ans:______

c) How many nodal lines will be produced?

Ans:______

10. a) <u>Completely</u> describe an experiment where you could use the ideas of this chapter to measure the wavelength of light:

b) <u>Completely</u> describe an experiment where you could use the ideas of this chapter to measure the wavelength of soun[d] wa[ves] sequence show a traveling wave or a standing wave? (b) If the sequence shows a traveling wave, in which direction is it moving?

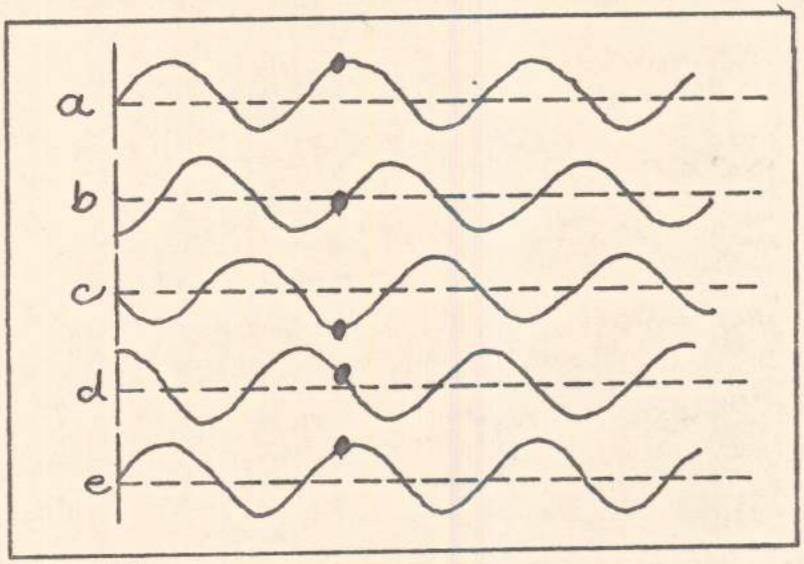


Fig. 27

5. Fig. 28 shows several modes of possible vibration of a string anchored rigidly at both ends. Drawing (a) shows shows the fundamental mode of vibration. The fundamental is also called the first harmonic. Drawing (b) shows a mode of vibration called the 2nd. harmonic.
   a) Sketch the 3rd. and 4th. harmonics in the spaces provided.
   b) In drawings: a, b, c, and d, label all nodes N and all antinodes A.
   c) In each of the four cases, express the wavelength λ, in terms of the length of the string, L.
   d) Assuming the velocity of the waves on the string to be constant, what would be the net result of decreasing L?

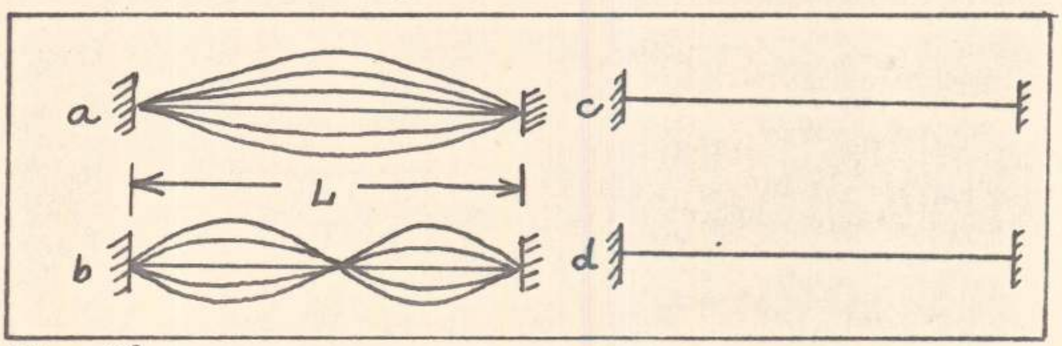


Fig. 28

☐ Work Sheet W-12 Open And Closed Pipes

☐ Text	Chap.	17-2	Interference From two Point Sources
☐ Loop		80-23971	Superposition of Pulses
☐ Loop		80-24051	Interference of Waves
☐ Text	Page	292	Homework problems: 4, 7, 8, 9
☐ Work Sheet		W-13	Chapter 17 Problems 5 and 6
☐ Text	Chap.	17-2	Reading Quiz

1. What is the meaning of the term phase?
2. Fig. 29 shows the positions of several water waves at some given instant. The waves were generated by two point sources S_1 and S_2. The solid lines represent wave crests and the dashed lines represent the troughs.
   a) Are the sources in or out of phase?
   b) What letter(s) indicate the points of maximum water depth?
   c) What letter(s) indicate the points of minimum water depth?
   d) What letter(s) indicate the points where the water is undisturbed?
   e) Sketch in the nodal lines.
   f) Would S_1 in operation alone generate standing or traveling waves?
   g) If S_1 and S_2 were generating monotone (one frequency) sound waves, describe the phenomena a listener would encounter in walking from Q to R; from S_1 to S_2.

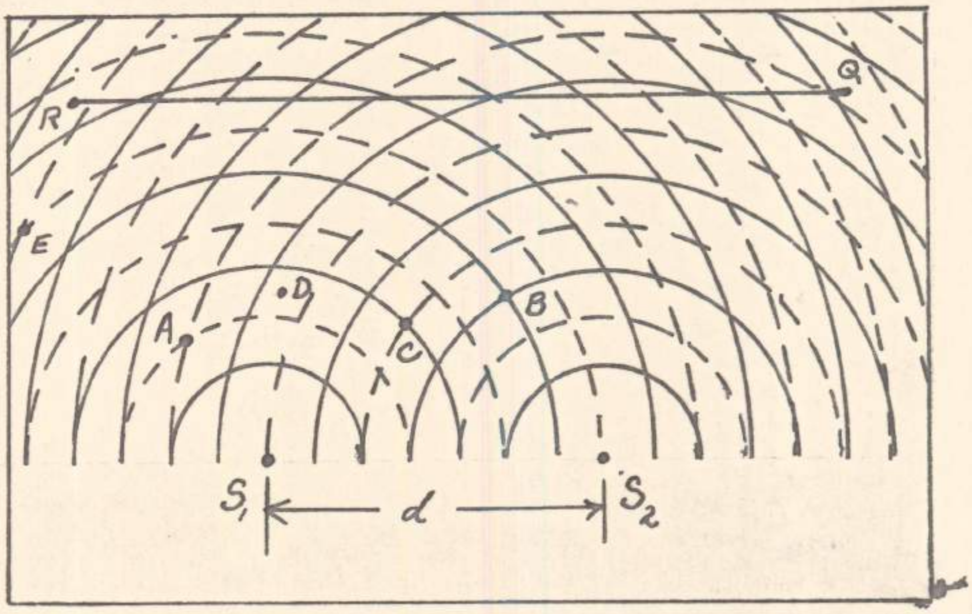


Fig. 29.

3. What effects on the nodal pattern would you expect in Fig. 29 as the result of increasing the separation of the sources, d?

☐ Text Chap. 17-3 The Shape of Nodal Lines

☐ Text Page 293 Homework problems: 10, 11, 12*, 13

☐ Text Chap. 17-3 Reading Quiz

1. How would an increase in wave length effect the number of nodal lines in the arrangement shown in Fig. 29, question 2 of the above Reading Quiz.
2. How is an hyperbola defined in Analytical Geometry?
3. In order for distructive interference to occur at a point in Fig. 29, above section, the difference in path lengths, ($PS_1 - PS_2$) must equal an (even, odd) number of (λ, $\lambda/2$, $\lambda/3$, $\lambda/4$, none of these).
4. In question 2e of Reading Quiz section 17-2, you were asked to sketch in all the nodal lines in Fig. 29. Pick any point on the 3rd. nodal line and label it point P. Complete the following equation:

$$PS_1 - PS_2 \quad \_\_\_\_\_\_\_\_\_\_.$$

5. What is the general expression for the difference ($PS_1 - PS_2$) for any point P on the nth. nodal line? Fig. 29.

☐ Text Chap. 17-4 Wavelengths, Source Separation, and Angles

☐ Text Page 293 Homework problems: 14, 15*, 16, 17*, 18, 19*

☐ Resource Bk Check homework problems: 1 - 19

☐ Work Sheet W-14 Quiz Section 17-4

☐ Text Lab II-11 Waves From Two Point Sources (part II)

☐ Text Lab II-12 Interference and Phase

☐ Text Chap. 17-5 Phase

☐ Loop 80-24131 Effect of Phase Differences Between Sources

☐ Text Page 293 Homework problems: 20*, 21*, 22*, 23*, 24*, 25*

☐ Resource Bk.			Check homework problems: 20 - 25
☐ Work Sheet		W-15	Quiz Section 17-5
☐ Text	Chap.	17-6	Summary and Conclusion
☐ Text	Page	294	Homework problems: 26*, 27*, 28, 29
☐ Resource Bk.			Check homework problems: 26 - 29
☐ Text	Page	294	Further Reading
☐ Text	Chap.	18-1	Can We See Interference in Light?
☐ Text	Page	312	Homework problems: 1, 2
☐ Text	Chap.	18-1	Reading Quiz

1. For a given wavelength, how does the separation of the nodal lines formed by the interference of two point sources change as the separation of the two sources changes? Illustrate your answer.

2. Use a mathematical argument to show why point sources of light must be much closer together, in order to get a measurable separation of nodal lines at convenient distances from the source, than point sources in a ripple tank.
3. Why are monochromatic sources of light used in interference experiments?
4. Here is an arrangement of two independent light sources and a screen that resembles the setup for producing interference in a ripple tank, Fig. 30. Why is it impossible to observe any interference pattern with this set up? Sketch a modification of the setup that will remedy the difficulty.

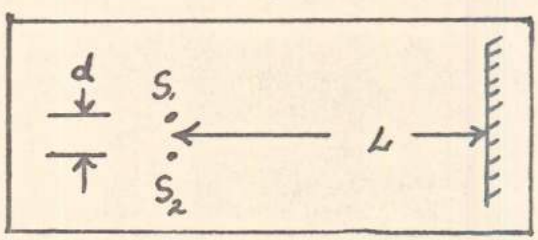
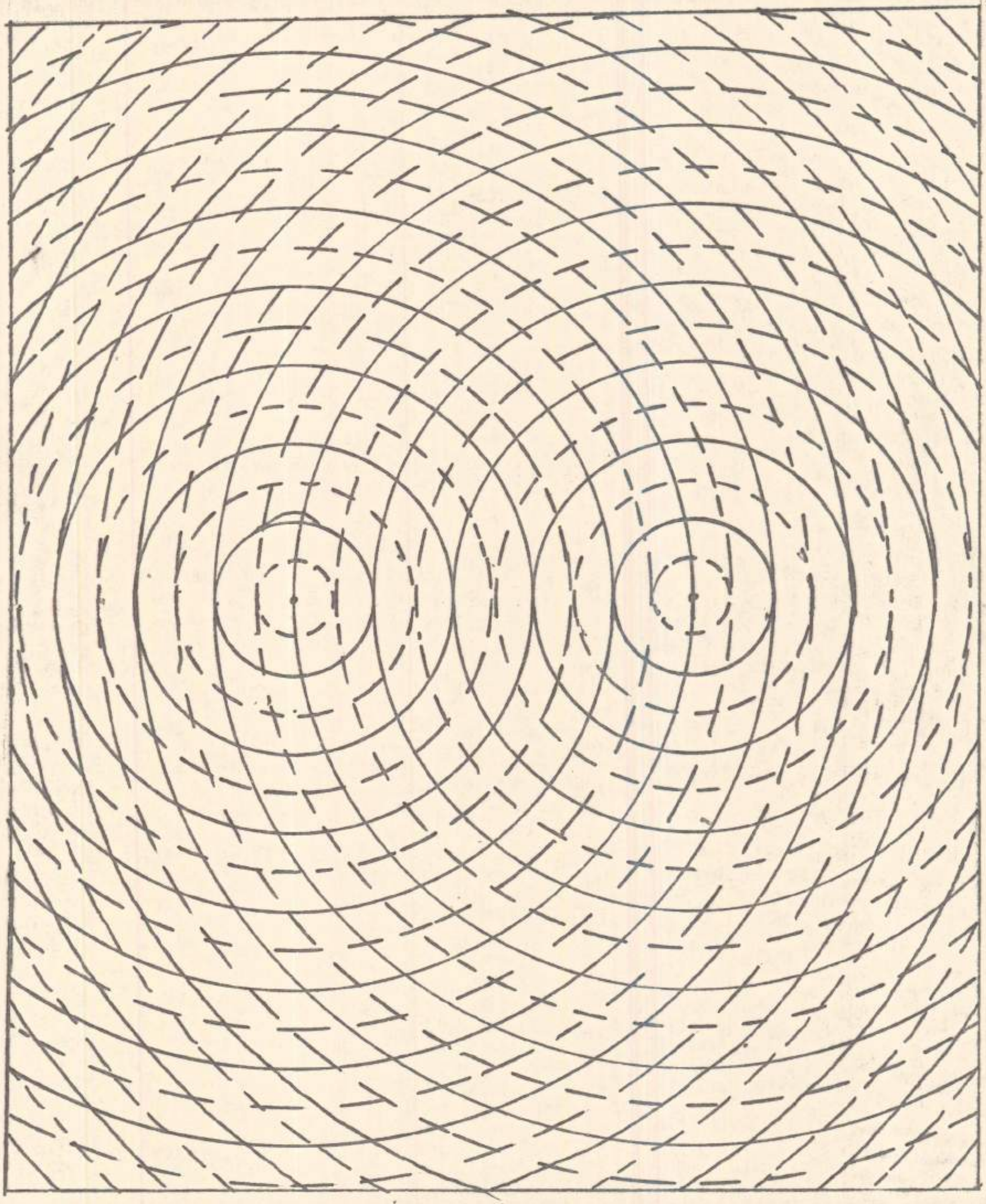


Fig. 30.

WORK SHEET 13 (W-13)

CHAPTER 17 PROBLEMS 5 AND 6



WORK SHEET 14 (W-14)

QUIZ SECTION 17-4

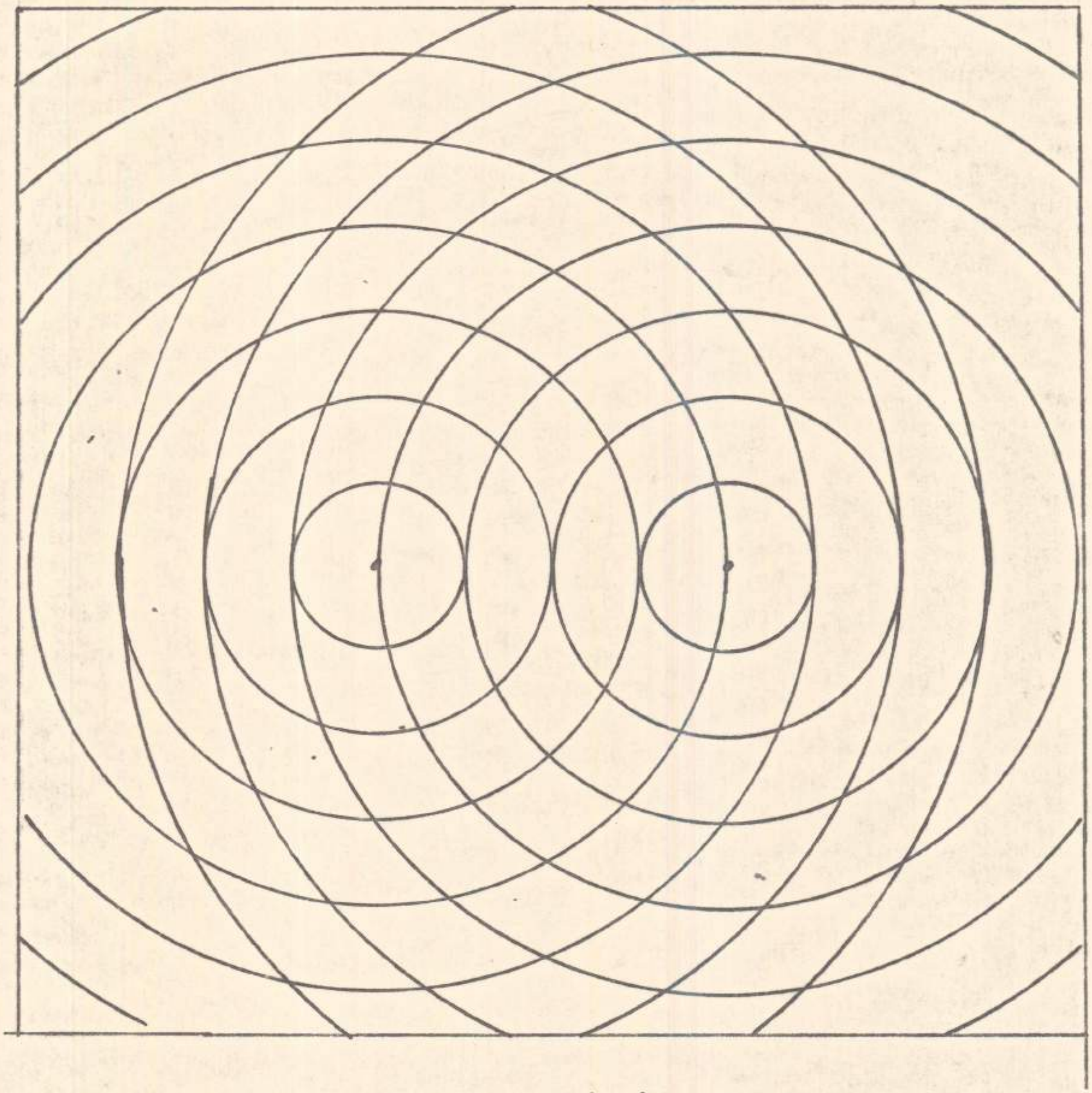
1. Given the two focal points, S_1 and S_2, and the formula for finding any point P on an hyperbola ($PS_1 - PS_2 = K$), construct the hyperbola.

K

WORK SHEET 14 (W-14) Continued

QUIZ SECTION 17-4

2. Sketch the nodal lines. Crests were made by two point sources in phase. Number the nodal lines.



3. Show that $PS_1 - PS_2 = (n - 1/2)\lambda$. Use the above figure to sketch any lines to show the above. Use back of page one for formulas.

4. Make a sketch and state reasons (if you think reasons are needed) to prove, $\lambda = d(X_n/L)/(n - 1/2)$. Use the back of this sheet for your work.

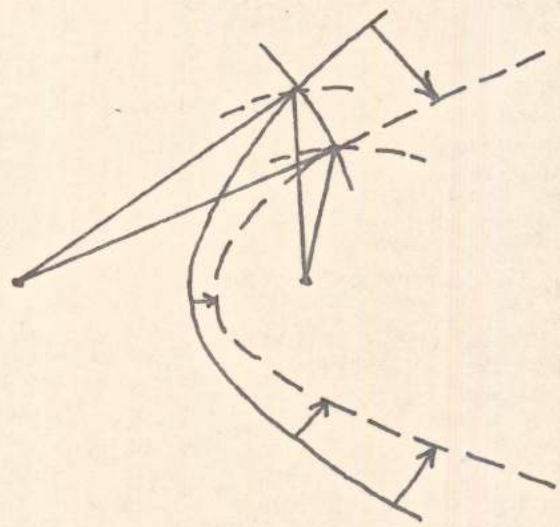
WORK SHEET 15 (W-15)

QUIZ SECTION 17-5

1. a) Label points and line segments in this diagram.

   b) Write a short description of what the diagram is representing in the ripple tank.

   c) Show that $P'S_1 - P'S_2 = (p + n - 1/2)\lambda$.



HIRAM COLLEGE · HIRAM, OHIO 44234 · TELEPHONE (216) 569-3211

DEPARTMENT OF PHYSICS
March 28, 1972

Dick Heckathorn
Midpark High School
7000 Paula Drive
Cleveland, Ohio 44130

Dear Dick:

You have an interesting paradox in your interference problem. The difficulty lies, I think, in the term "no interference." The values of θ that satisfy the equation $\sin\theta = n\frac{\lambda}{w}$ are the values of θ for which the intensity is zero. Now, for n=1 and $\lambda > w$ it is certainly true that $\sin\theta > 1$, but that means that there is no corresponding θ not that there is no interference. That is, the intensity is not zero for any angle.

To see what this implies consider the case where $\frac{\lambda}{w}$ begins to increase toward 1. At first the angle θ of the first minimum moves out toward 90°, then past 90°--that is, behind the plane of the slit. (This is not impossible if we think of a source of light instead of a real slit.) Finally, when $\frac{\lambda}{w} = 1$, the direction of the first minimum becomes 180°--directly behind the "slit". After this the intensity is not zero anywhere, but is less behind the "slit" than in front, and as $\frac{\lambda}{w}$ continues to increase the back and front intensities become more nearly the same: We are appraoching the case of a geometrical line source.

To put it briefly, as λ increases or w decreases, the broad central maximum of intensity spreads out over larger and larger angles, until the intensity becomes more or less uniform all around the slit.

It should be apparent now, that to get the smallest possible "image" of the slit (that is, to make the diffraction pattern as narrow as possible) you should use the largest slit possible. One reason the telescope on Mt. Palomar is 200 inches across is to give the best possible resolution. If you try to carry this to extremes in the lab, however, you soon find that the "image" of your slit is getting larger as the slit gets larger. This is because the equations we have used depends on an approximation (the Fraunhoffer Approximation) which breaks down when the slit is too wide or the viewing screen is too close to the slit. Technically the approximation is $\lambda R/w^2 << 1$, where R is the slit-to-screen distance. If a lens is placed after the slit and the screen placed at the focal point, it is equivalent to having the screen at infinity and the approximation holds for all values of w. Then when the slit is very wide the pattern on the screen will approach a point, which is just what we get at the focal point with no slit present at all (i.e., an infinitely wide slit).

I hope this isn't too long winded or too trivial for you, but it is an interesting problem, which intelligent students do raise now and then. I'm glad to be able to help.

Sincerely,

Don

Donald R. Wheeler

P.S. We've had good response to the Summer Institute questionaires, and I'll be in touch shortly.

DRW:lh

NAME ____________

Questions 8–10: A straight wave moving from medium 1 to medium 2 is refracted at the interface. The direction of propagation shown.

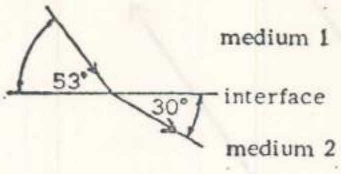


Table of Sines
30° = 0.5
37° = 0.6
53° = 0.8
60° = 0.9

Let v_1 and v_2 denote the velocities of the wave in media 1 and 2, respectively.

8 Which one of the following could be the angle between the interface and the refracted wave crest?

A 23°
B 30°
C 37°
D 53°
E 60°

8. E

9 What value for v_2/v_1 is predicted by the wave model of light?

A 4/9
B 2/3
C 1/1
D 9/4
E 3/2

9. E

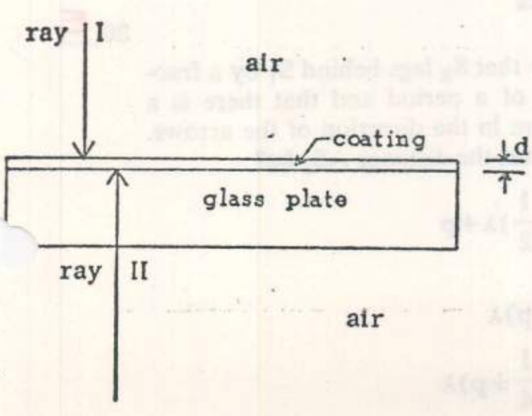
10 What is the value of the ratio,

$$\frac{v_2/v_1 \text{ predicted by the particle model}}{v_2/v_1 \text{ predicted by the wave model}} ?$$

A 4/9
B 2/3
C 1/1
D 9/4
E 3/2

10. A

Questions 11–12: Some glass plates are coated with thin films to decrease the amount of reflection that would occur at the coated surfaces:



The thickness, d, and refractive index, n_c, of the coatings are varied to give different effects. In the following key, n_g represents the refractive index of the glass plates and λ represents the wave length of light in the coatings. The refractive indices, n_c, of the coatings are always greater than that of air.

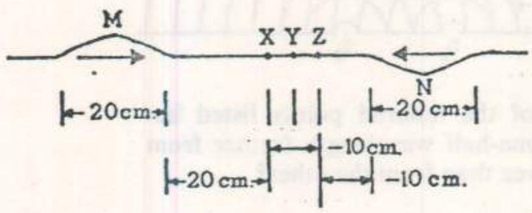
Key:

A $d = \lambda/4;\ n_c < n_g$
B $d = \lambda/2;\ n_c < n_g$
C $d = \lambda;\ n_c < n_g$
D $d = \lambda/4;\ n_c > n_g$
E $d = \lambda;\ n_c = n_g$

11 What combination of d and n_c would give minimum reflection of ray I? 11. A

12 What combination of d and n_c would give minimum reflection of ray II? 12. A

Questions 13–15 refer to the diagram below:



Two triangular-shaped pulses, identical in shape but opposite in displacement, travel toward each other along a rope. The length of the displaced portion of each pulse is 20 cm. and the points of maximum displacement, M and N, are each 10 cm. from the leading edge of their respective pulses. M and N are each displaced 4.0 cm. from the rest position of the rope.

13 Point X is midway between the pulses. As the pulses pass through X, what is the maximum displacement which X will undergo?

A zero cm.
B 2.0 cm.
C 4.0 cm.
D 6.0 cm.
E 8.0 cm.

13. A

14 Point Y is 5 cm. to the right of point X. When the leading edges of the two pulses coincide at X, the displacement of Y from its rest position will be most nearly

A zero cm.
B 2.0 cm. downward.
C 4.0 cm. downward.
D 2.0 cm. upward.
E 4.0 cm. upward.

14. B

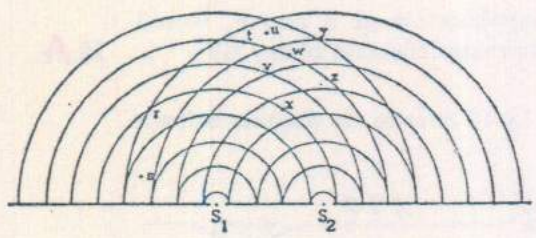
 Name ____________

15 What will be the maximum displacement which point Y will undergo during the passage of these two pulses?

A zero cm.
B 2.0 cm.
C 4.0 cm.
D 6.0 cm.
E 8.0 cm.

15. C

Questions 24–26 refer to the diagram below, which shows ripples from sources S_1 and S_2 in a ripple tank. Various points r through z are marked on the diagram. The lines represent wave crests.



24 Which of the lettered points listed below is one-half wavelength farther from one source than from the other?

A r
B u
C x
D y
E z

24. C

25 Which of the lettered points listed below represents a double crest which is one wavelength farther from one source than from the other?

A u
B v
C w
D y
E z

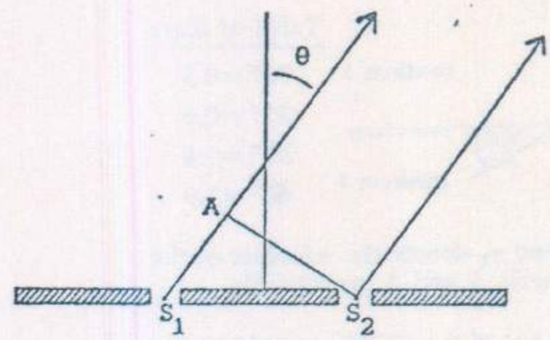
25. D

26 Which one of the pairs of lettered points listed below lies on a single nodal line?

A x and z
B w and x
C u and v
D v and x
E r and v

26. B

Questions 29–31: Two point sources, S_1 and S_2, emit waves of the same frequency. n is an integer.



29 Suppose that the sources are in phase and that there is a maximum in the direction of the arrows. What must the distance AS_1 be?

A $(n-\frac{1}{2})\lambda$
B $n\lambda$
C $(n+\frac{1}{2})\lambda$
D $(n-\frac{1}{4})\lambda$
E $n\lambda+\frac{1}{2}$

29. B

30 The maximum resulting from the interference pattern shifts so that the angle θ, describing the direction to the maximum, increases. This change can be accounted for by which one of the following?

A Moving the point of observation farther away from the two sources
B Increasing the separation of the two sources
C Decreasing the wavelength of the two sources
D Increasing the frequency of the two sources
E Decreasing the separation of the two sources

30. E

31 Suppose that S_2 lags behind S_1 by a fraction, p, of a period and that there is a maximum in the direction of the arrows. What must the distance AS_1 be?

A $(n-\frac{1}{2})\lambda+p$
B $np\lambda$
C $(n+p)\lambda$
D $(n-\frac{1}{4}+p)\lambda$

Page 3 NAME ______________

18 + 14 = 32 TOTAL

1. A point on the third NODAL line is found to be 40.8 cm from one source and 42.7 cm from the other. (a) What is the path difference? (b) What is the wave length? (c) If the sources are 9.3 cm apart, what is the interference angle of this line? (d) How many nodal lines are there?

12

$n = 3$

$PS_1 = 40.8$ cm

$PS_2 = 42.7$ cm

$d = 9.3$ cm

a. 1.9 cm 3

b. 0.76 cm 3

c. 11.79° 3

d. 12 3

(a) $42.7 - 40.8 = 1.9$ cm

(b) $\lambda = \frac{\Delta d}{n - 1/2} = \frac{1.9 \text{ cm}}{2.5}$

(c) $\lambda = \frac{d \sin\theta}{n - 1/2}$; $\sin\theta = \frac{\lambda}{d}(n - 1/2) = \frac{0.76 \text{ cm}}{9.3 \text{ cm}}(2.5) = .204$

(d) $n = \frac{d}{\lambda} + \frac{1}{2} = \frac{9.3 \text{ cm}}{0.76 \text{ cm}} + .5 = 12.74$

2. Two loudspeakers are located 6.3 meters apart at the front of an auditorium. A test record on which was recorded a certain sound of constant frequency is played through the above speaker system. An observer hears the sound loud and clear when standing anywhere in the center aisle, but hears "dead spots" in the auditorium as he moves about from place to place. He attaches a rope of 18 meters long to a point midway between the speakers. He then moves in an arc and discovers the first dead spot 3.1 meters to the right of the center aisle. What is the wave length of the sound reproduced by the test record?

3 2.17 M

$d = 6.3$ M

$L = 18$ M

$X_1 = 3.1$ M

$n = 1$

$\lambda =$

$\lambda = \frac{d x_n / L}{n - 1/2} = \frac{6.3 \text{ M} \cdot 3.1 \text{ M}}{18 \text{ M} \cdot 0.5} = 2.17$

3. How far apart must two point sources be placed in a ripple tank in order for the second nodal line to be at 30° if the wave travels at 24 cm/sec and the frequency is 13/sec?

3 5.54 cm

$n = 2$

$\theta = 30°$

$d = ?$

$v = 24 \frac{\text{cm}}{\text{sec}}$

$f = 13/\text{sec}$

$\lambda = \frac{v}{f}$

$\lambda = \frac{d \sin\theta}{n - 1/2}$

$d = \frac{\lambda (n - 1/2)}{\sin\theta}$

$= \frac{v}{f} \frac{(n - 1/2)}{\sin\theta}$

$= \frac{24 \text{ cm/sec}}{13 \text{ sec}} \times \frac{1.5}{\sin 30°} = 5.538$ cm

18

14 X ~~2 = 28~~.

8. A B C D E

9. A B C D E

10. A B C D E

11. A B C D E

12. A B C D E

13. A B C D E

14. A B C D E

15. A B C D E

24 A B C D E

25 A B C D E

26 A B C D E

29. A B C D E

30. A B C D E

31. A B C D E

Draw in θ
Add # 8
Line Crest
1a 1b 1c

(36)

TEST CHAPTER 24 NAME Key d = 3

1. Attached to this quiz is a representation of an interference pattern produced by two point sources of waves.

   A. Carefully draw and label the following:
   a. the central maximum
   b. the third nodal line
   c. the locus (i.e. set) of points that are one wavelength further from S1 than from S2.

   6

   B. Calculate the angle to the third maximum line using d sin θ for the path difference. $\lambda = \frac{d \sin\theta}{n}$; $\sin\theta = \frac{n\lambda}{d}$ = $\Delta d = d \sin\theta \Rightarrow \sin\theta = \frac{\Delta d}{d}$ 3
   90°

   2

   C. Using the attached diagram, pick a point on the third maximum line and draw a line connecting this point with the point midway between the sources. Measure the angle between this line and the central maximum. If all drawings, measurements, and calculation are perfect, do you expect this angle to be equal to the answer in (B) above. If not which do you expect to be larger and why? $\frac{3\lambda}{3\lambda} = 1$

   2

   $\theta = 90°$ $\sin\theta = \frac{x_n}{L}$ $x_n = L$ ∴ $\theta = 90°$

2. When we were analyzing two point interference patterns, why did we develop two different equations for path difference?

   Nodal - Anti-nodal

   2

3. Describe two independent ways you could decrease the number of nodal lines that are present in a two point interference pattern.

   (1) decrease f
   (2) decrease d

   2

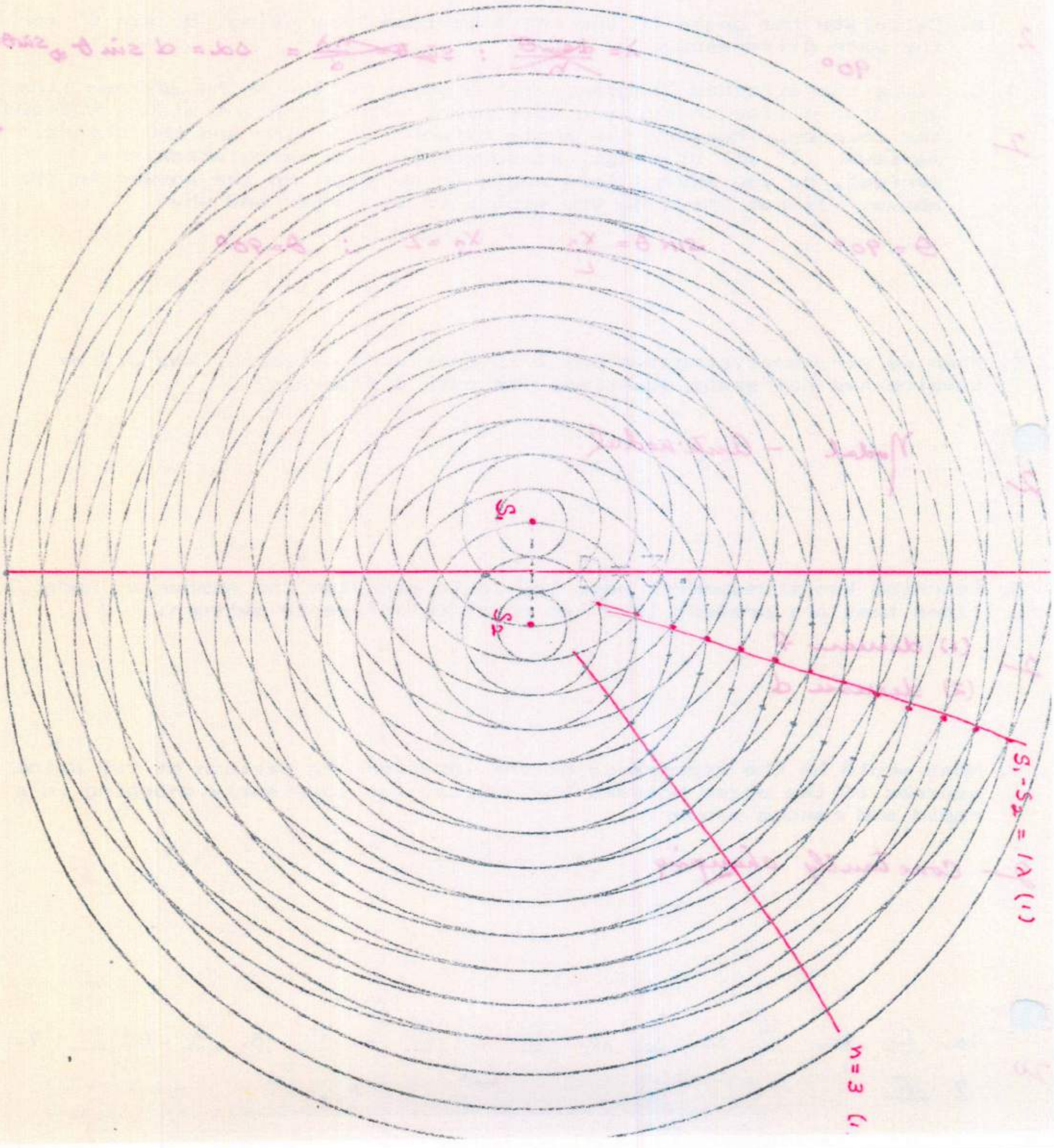
4. What would be the appearance of the interference pattern of two point sources if the phase between the sources was constantly changing in a rapid and random manner?

   2 constantly changing

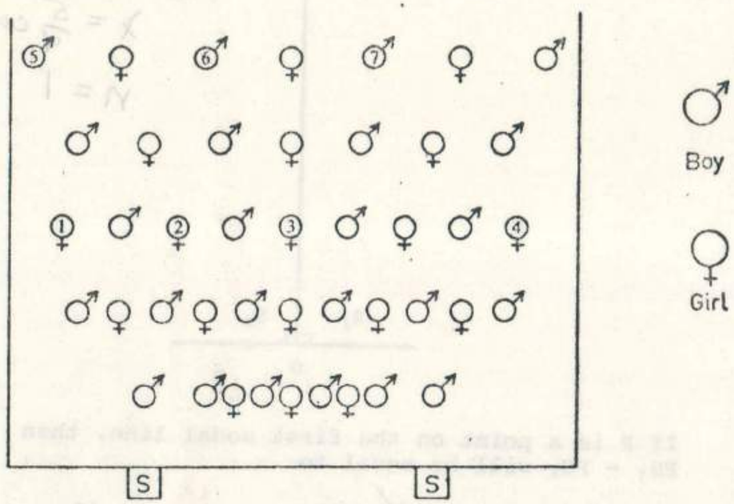
1a. C 1b. B 1c. C 2. B 3. D 4. C 5. B 6. D 7. C

20

8. E


S1
S2
S1-S2 = 1λ (1)
n=3 (

1a. On a day when there is no wind, a loudspeaker S is placed at each goalpost at one end of a football field. The loudspeakers are in phase and are emitting sounds of the same constant frequency and intensity. The boys in a class are asked to find positions on the field where the sound is faintest and the girls to find positions where the sound is loudest. The positions taken are shown in the diagram below.



Which one of the following changes would result in the students standing closer together?

(A) Increasing the wavelength of the note emitted

(B) Moving the loudspeakers closer together

(C) Increasing the frequency of the note emitted

(D) Choosing a day when the air temperature is much higher

(E) Putting the loudspeakers out of phase.

1b. Which girl is at a point one wavelength further from one loudspeaker than from the other?

(A) 1 (C) 3 (E) None of the above

(B) 2 (D) 4

1c. Which student is at a position with best satisfies the conditions $\frac{X}{L} = \frac{3\lambda}{2d}$?

X = the distance from the student to the right bisector of the line joining the loudspeakers

L = the distance of the student from the midpoint between the speakers

λ = the wavelength of the sound from the speakers

and d = the distance between the speakers

(A) 2 (C) 5 (E) 7

(B) 4 (D) 6

2. An interference pattern is produced by two point sources vibrating in phase in a ripple tank. If the frequency of the two point sources increases, the pattern

(A) has fewer nodal lines

(B) has more nodal lines

(C) remains the same

(D) spreads out farther into the ripple tank

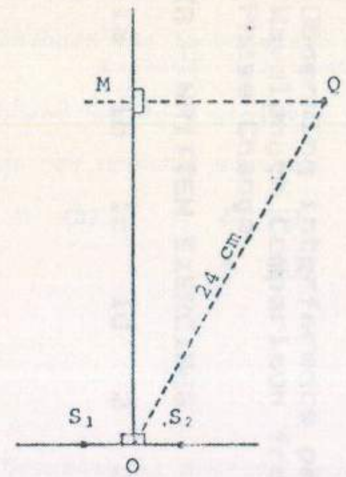
(E) spreads out less into the ripple tank

3. Two point-sources in a ripple tank vibrate in phase at a frequency of 12 Hz to produce waves having a wavelength 0.024 m. The difference in path-length from the two point-sources to a point on the second nodal line is

(A) 0.6 cm (C) 2.4 cm (E) 4.8 cm

(B) 1.2 cm (D) 3.6 cm

4. S_1 and S_2 are two point sources situated 6 cm apart, vibrating in phase, and producing waves having a wavelength of $\frac{5}{4}$ cm. (Diagram not drawn to scale.)



If Q is a point on the second nodal line, 24 cm away from O, then MQ is approximately

(A) 2.5 cm (B) 5 cm (C) 7.5 cm (D) 10 cm (E) 15 cm

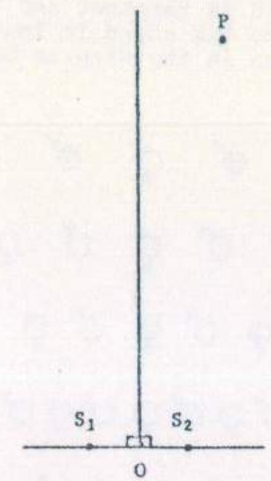
5. The distance between successive nodes in a standing wave pattern is

(A) 1/4 λ (B) 1/2 λ (C) 3/4 λ (D) 1 λ (E) 2 λ

6. A nodal line pattern is produced by two point sources vibrating in phase in a ripple tank. A point P is selected on the second nodal line so that it is 37 cm from one source and 28 cm from the other source. The wavelength of the waves in centimetres is

(A) 18 (B) 13.5 (C) 9.0 (D) 6.0 (E) 4.5

7. S_1 and S_2 are two point sources situated 6 cm apart, vibrating in phase, and producing waves having a wavelength of $\frac{5}{4}$ cm. (Diagram not drawn to scale.)



$d = 6$ cm
$\lambda = \frac{5}{4}$ cm
$n = 1$

If P is a point on the first nodal line, then $PS_1 - PS_2$ will be equal to

(A) $\frac{5}{48}$ cm (B) $\frac{5}{24}$ cm (C) $\frac{5}{8}$ cm (D) $\frac{5}{4}$ cm (E) $\frac{15}{8}$ cm

8. Two periodic point sources vibrating in phase produce an interference pattern on a water surface.

The path difference between the two point sources and a point on the n^{th} nodal line is

(A) $n\lambda$ (B) $(n - 1)\lambda$ (C) $(n + 1)\lambda$ (D) $(n + \frac{1}{2})\lambda$ (E) $(n - \frac{1}{2})\lambda$