17.1

Saturday, January 19, 2019 12:45 PM

- Surface wave: a wave that propagates in two dimensions.
- Point source: when the source of the wave can be localized to a single point in space
  - point sources are treated as if they have no physical extent.

    the actual source need not be physically small.
- Wavefront: Curves or surfaces on which all points have the same phase consistute a wavefront.

- Spherical waves: the resulting wave of spherical wavefront.

  (the source is a point source and the spreading is uniform in all three dims)
  - Spherical waves are always expressed as surface waves.

- The amplitude of waves in two dimensions decreases with distance r from the source as $\frac{1}{\sqrt{r}}$; in three-dim it decrease as $\frac{1}{r}$. The decrease is due purely to the spreading out of wavefronts & involves no loss of energy.

  $\because$ no loss of Energy

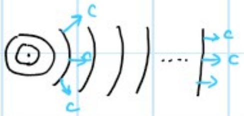
  $\therefore$ $E\downarrow$ two-dim: $E \propto \frac{1}{r}$ (per unit length) three dim $E \propto \frac{1}{r^2}$

  $E = \frac{1}{2}\mu\lambda\omega^2A^2$

  $\therefore$ $A \propto \frac{1}{\sqrt{r}}$ (two-dim) $A \propto \frac{1}{r}$ (three dim)

- Planar wavefront: Far from a point source, a spherical wavefront

- **Planar wavefront**: Far from a point source, a spherical wavefront essentially becomes a two dimensional flat wavefront.



  - At this time, amplitude change a little.

-
  - crest (highest point)
  - troughs

17.2

Saturday, January 19, 2019 4:12 PM

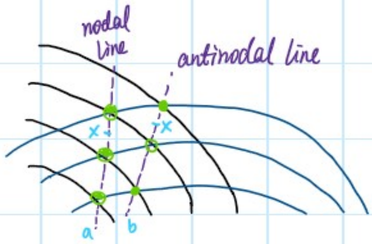
- Sound : longitudinal waves that human ear can detect.
    - Compression region where the molecules are crowded together.
      rarefaction region where they are spaced far apart.
      → compressional wave
    - c depend on the density & elastic properties
    - For dry air at a temperature of 20 °C, the speed of sound wave is 343 m/s
- The compressions and rarefactions in longitudinal waves occur at the location where the medium displacement is 0.

17.3 interference

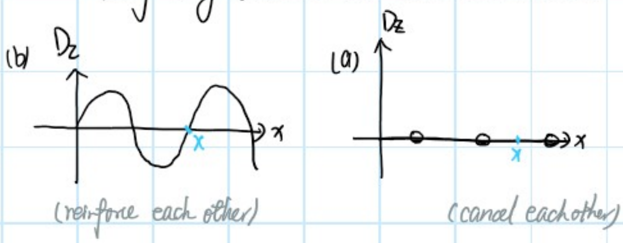
Monday, January 21, 2019 3:43 PM

- in phase : two waves having the same frequency, crossing x-axis at same point & same direction
  ⇔ having same phase
  out of phase : two waves having different phase
- coherent : Sources that're emitting waves that have a constant phase difference
- nodal lines : lines where the two waves cancel each other & vector sum of medium displacement is always 0.

antinodal lines



half-way between the nods & antinodes:



- When the waves from two coherent sources intefere, the amplitude of the sum of these waves in certain direction is less than that of a single source.
- If two coherent sources located d apart, emit identical λ, then the number of nodal lines on either side of a straight line running through the centers of the source is the greatest int $\leq \frac{2d}{\lambda}$
- When many coherent point source are placed close together along a straight line, the waves nearly cancel out in all directions except the direction perpendicular to the axis of sources.

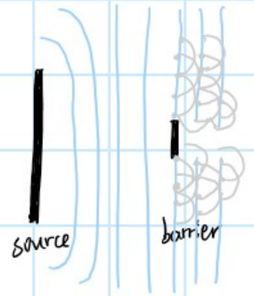
17.4 Diffraction

Monday, January 21, 2019 5:55 PM

- Huygen's Principle: any wavefront may be regarded as having originated from a collection of many closely spaced, coherent point sources emitting waves in all direction.
- Diffraction: when the gap width is smaller than the wavelength, the wavefronts beyond the gap spread out in all directions — in essence, the gap now acts like a single point source.
  - diffraction is another characteristic feature that distinguish waves from objects.
    - Waves spread out when going through a narrow opening, but objects do not.

- Obstacles or apertures whose width is smaller than the wavelength of an incident wave give rise to considerable spreading of that wave.
  - $f_1 > f_2$ sound 2 diffract more strongly.
  - It's impossible to create a beam of waves that is narrower than the wavelength of the waves.

e.g.



17.5, 17.6 intensity, beats

Tuesday, January 22, 2019 12:22 AM

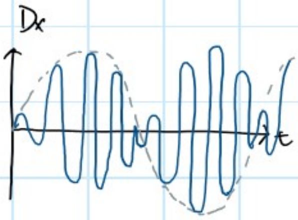
- Intensity
  - Waves in 3-dim : the energy delivered by the wave per unit time per unit area normal to direction of propagation.
    $I = \frac{P}{A}$ (W/m^2)
    $I = \frac{P_s}{A_{sphere}} = \frac{P_s}{4\pi r^2}$
  - Waves in 2-dim : the energy incident per unit time per unit length normal to direction of propagation
    $I_{surf} = \frac{P}{L}$

  - Intensity level (β)

    $\beta = (10\,dB)\log\left(\frac{I}{I_{th}}\right)$ (bel B) (dB decibels), $I_{th} = 10^{-2}\ W/m^2$

    - $1\,dB = 0.1B$
    - I_{th} : intensity at the threshold of hearing
    - Make people easier to communicate about loudness.

- Beats : the resultant wave (changes amplitude) of two waves with same amplitude and slightly different f.

  - 

  - beat frequency $f_{beat} = |f_1 - f_2|$

    $nT_f = (n+1)T_y \Rightarrow n = \frac{T_y}{T_f - T_y}$ (assume $f_y > f_f$)

    $t_{overtake} = nT_f = \frac{T_y T_f}{T_f - T_y}$

    $f_{overtake} = \frac{1}{t_{overtake}} = \frac{1}{T_y} - \frac{1}{T_f} = f_y - f_f$

  - $D_x = 2A\cos[2\pi(\frac{1}{2}\Delta f)t]\sin(2\pi f_{avt})$

    $f_{beat} = |f_1 - f_2|$

e.g.

One way to tune a piano is to strike a tuning fork (which emits only one specific frequency), then immediately strike the piano key for the frequency being sounded by the fork, and listen for beats. In making an adjustment, a piano tuner working this way causes the beat frequency to increase slightly. Is she going in the right direction with that adjustment?

A. Yes

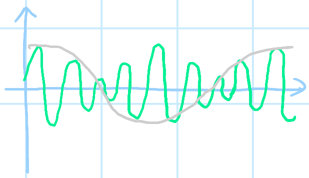
B. No

Correct Answer :

B In order to be tuned we want the beat frequency to approach zero.

e.g. Does two sound waves of slightly f and different A cause e.g. Does two sound waves of slightly f and different A cause beats?

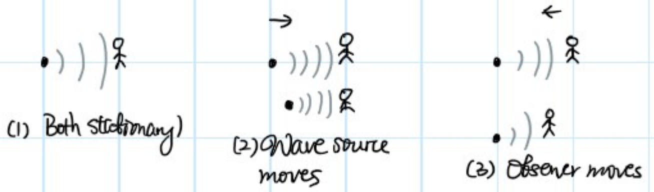
Yes. The beats are less pronounced, the amplitude never goes all the way to 0.



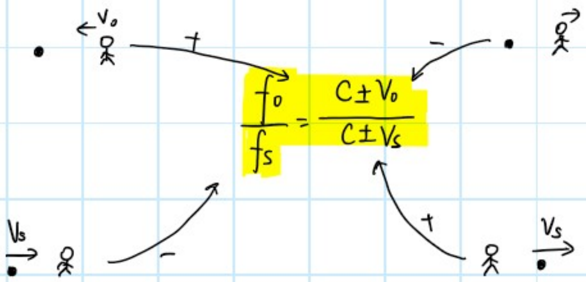
17.7 Doppler effect

Tuesday, January 22, 2019 7:10 AM

- Doppler effect: When observer and source move toward each other, the observed frequency is higher than the emitted frequency; when they move away from each other, the observed frequency is lower than the emitted frequency.
    - Although motion of wave source & observer (towards) both increase f, the amount is not the same. Since motion of wave source changes λ.



- $V_s < C$ (speeds are measured relative to the medium)



$$\frac{f_o}{f_s} = \frac{C \pm V_o}{C \pm V_s}$$

e.g. A buzzer emits a sound at a constant frequency f_S. Your instructor spins the buzzer around in a circle of radius 1 m with a period of 0.5 s, so that the maximum speed of approach and retreat is v_S=12.6 m/s. When the buzzer approaches and retreats with maximum speed you hear a frequencies f_a and f_r, respectively. What is the ratio of the frequencies f_a/f_r ?

Note the speed of sound is 343 m/s.

$$f_a = \frac{c}{c - V_s} \cdot f_s$$

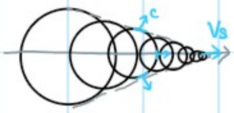
$$f_r = \frac{c}{c + V_s} \cdot f_s$$

$$\frac{f_a}{f_r} = \frac{c + V_s}{c - V_s} = 1.076$$

17.8 Shock waves

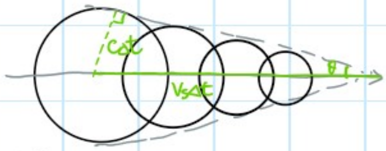
Tuesday, January 22, 2019 11:57 PM

- Shock wave: the wedge-or cone-shaped-wavefront occurs whenever the speed of any object moving through a medium is higher than the speed of sound in the medium, even if the obj emits no sound.



$V_s > C$

o $\sin\theta = \frac{c}{V_s}$

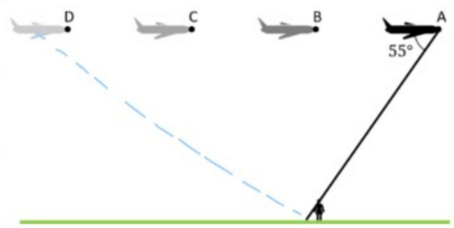


o Mach number $\frac{V_s}{c}$

e.g.

multiple choice question

A woman standing on the ground observes a jet flying directly overhead. When the jet is at position A she hears a sonic boom from the shock wave indicated. Where was the jet located when it produced the sound she heard?



$\sin\theta = \frac{c}{V_s}$ D

$\frac{ct}{V_s \cdot t} = \sin\theta \Rightarrow \frac{\Delta x_c}{\Delta x_{plane}} = \sin\theta$

should be on the tangent line.

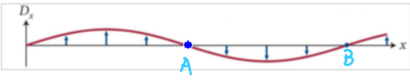
Probs

Tuesday, January 22, 2019 1:46 PM

☆☆☆☆☆

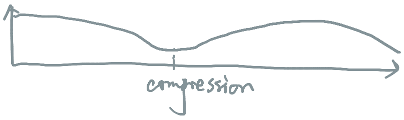
Sound waves consist of longitudinal waves propagating through any kind of material. The diagram shows the displacement of air molecules in a sound wave traveling through air in the x direction. On the diagram indicate an x position where the density of the air molecules is maximum.

Your response:



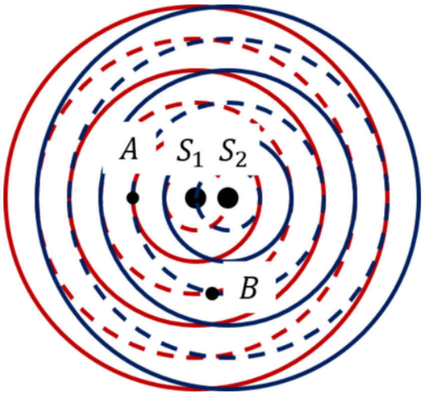
At node A: tends to move towards A.

At node B: tends to move awae from A.



many choice question

Surface waves are generated from two coherent sources, S_1 and S_2 separated by a small distance. The figure shows the crests (solid) and troughs (dashed) of the waves from S_1 (red) and S_2 (blue) at an instant when the displacement at point A is zero and the displacement at B is minimum. What are the displacements at points A and B when the wavefronts have travelled outward half a wavelength? Select all that apply. Assume the amplitudes of the waves do not decrease with distance from the source.



A. Point A is still has zero displacement

B. Point A is now a maximum

C. Point A is now a minimum

D. Point B is still has a minimum

E. Point B is now has zero displacement

F. Point B is now a maximum

if it's $\frac{1}{4}\lambda$, the B is 0. AF

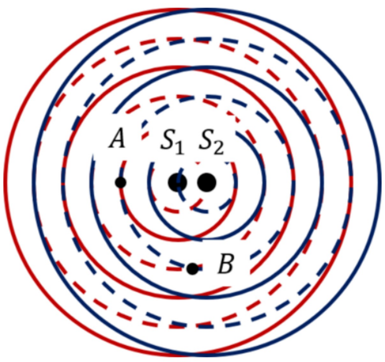
if it's $\frac{1}{2}\lambda$, B is maximum.

☆☆☆☆☆

many choice question

Surface waves are generated from two coherent sources, S_1 and S_2 separated by a small distance. The figure shows the crests (solid) and troughs (dashed) of the waves from S_1 (red) and S_2 (blue) at an instant. Then the frequency of the sources are doubled. Are points A and B now on nodal lines or antinodal lines? Select all that apply.

Assume the amplitudes of the waves do not decrease with distance from the source.



many choice question

Surface waves are generated from two coherent sources, S_1 and S_2 separated by a small distance. The figure shows the crests (solid) and troughs (dashed) of the waves from S_1 (red) and S_2 (blue) at an instant. Then the frequency of the sources are doubled. Are points A and B now on nodal lines or antinodal lines? Select all that apply.
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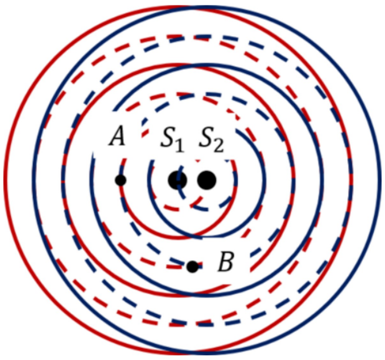


A. Point A is now on a nodal line

B. Point A is now on an antinodal line

C. Point B is now on a nodal line

D. Point B is now on an antinodal line

$f \to 2f$

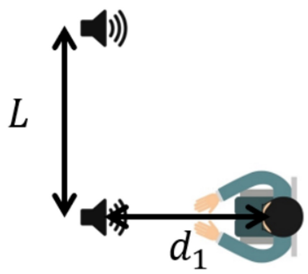
$\lambda \to \frac{\lambda}{2}$

$\frac{2d}{\lambda}$

BD

multiple choice question

A pair of in-phase stereo speakers is placed side by side, separated by a distance of L= 1.43 m. You are sitting a distance d_1=0.94 m directly in front of one of the speakers. The speakers play a constant note with frequency of 2000 Hz. Assuming the speed of sound is 343 m/s, do you hear constructive or destructive interference?



A. Constructive

B. Destructive

C. Neither

B

$\lambda = \frac{343\,m/s}{2000\,Hz} = 0.1715\ m$

$\frac{d_1}{\lambda} = 5.48$

$\frac{\sqrt{L^2+d_1^2}}{\lambda} = 9.98$

$9.98 - 5.48 = 4.5$ wavelength

$\therefore$ destructive.

A woman standing on the ground observes a jet directly overhead flying at an altitude of 20,000 m .

Part A

If the jet has a speed of Mach 2 and its shock wave makes an angle of 30° with the horizontal, how long will it be until she hears the sonic boom?

Express your answer with the appropriate units.

$\Delta t =$ 50 s

A woman standing on the ground observes a jet directly overhead flying at an altitude of 20,000 m .

Part A

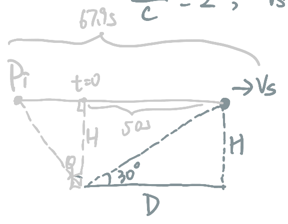
If the jet has a speed of Mach 2 and its shock wave makes an angle of 30° with the horizontal, how long will it be until she hears the sonic boom?

Express your answer with the appropriate units.

Δt = 50 s

Submit Previous Answers

$\frac{V_s}{c} = 2$, $V_s = 2 \times 340\ m/s$



$\Delta t = \frac{D}{V_s} = \frac{H}{\tan\theta V_s} = 50s$

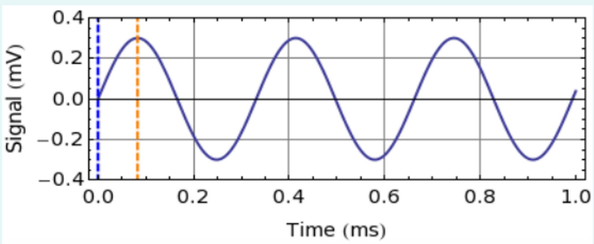
- A octave apart: $f_1 : f_2 = 2:1$

Part 3: Measure speed of sound

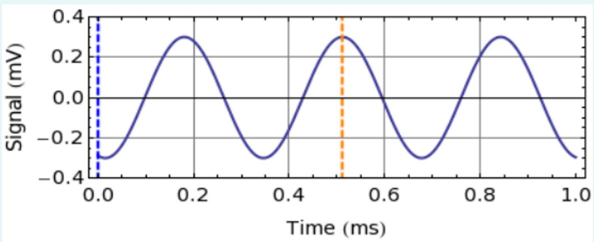
In this part of the lab you tracked a single peak as you moved a microphone in order to get a good value of the speed of sound. This question will lead you through a similar process with just two measurements.

The graphs below show two sine-wave signals like you saw from a microphone positioned in front of a speaker in Part 3 of the experiment. The two dashed vertical lines represent the cursors of the oscilloscope, with the one on the right side (colored orange) tracking a peak of the sound wave as the microphone is moved. The position x of the microphone in front of the speaker and the time between the cursors Δt is shown below each graph.

time between the cursors Δt is shown below each graph.



Mic position: x = 5.00 cm. Cursor difference: Δt = 0.0828 ms



Mic position: x = 20.0 cm. Cursor difference: Δt = 0.511 ms

For all entries, your answers must be correct to within 2%.

Part A

What is the speed of sound indicated by the above graphs?

350 m/s

Submit Previous Answers

Correct

In the top graph the phase difference between the two cursors is π/2 radians.

Part B

What is the frequency?

3020 Hz

$x = A\sin(\underbrace{\omega t}_{\text{phase}} + \phi_i)$

phase difference = $\Delta(\omega t) = \omega \Delta t = \frac{\pi}{2}$

$f = \frac{\omega}{2\pi} =$

$\omega = \frac{\pi}{2} / 0.0828 \approx 18.97$

(time unit: ms)