Physics 123 Waves and Sound Review

I. Definitions and Facts

longitudinal wave	transverse wave	traveling wave
standing wave	wave front	wavelength
wave number	frequency	angular frequency
period	crest	trough
node	antinode	transmission
reflection	diffraction	velocity of sound = 330 m/s
Doppler shift	pitch	constructive interference
destructive interference	shock wave	beats
harmonics	overtones	amplitude

II. Mathematics

translation: $f(x+x_0)$ is $f(x)$ moved “left” by x_0.
partial derivatives
differential equations: be able to show a function is a solution
Fourier transform: gives frequency components of a wave

III. Basic Concepts

application of Newton’s laws to a segment of string gives rise to the wave equation -the force is proportional to the curvature of the string at a point. So curvature = constant x acceleration.

many (quantities including displacement, pressure, electric and magnetic fields) obey the wave equation

any function $f(u)$ with $u=kx\pm\omega t$ satisfies the wave equation

the superposition principle

any function can be composed of a sum of sine waves

when a wave goes from one medium to another both reflection and transmission occur

when a wave goes from a less dense medium to a more dense medium, the reflected wave is inverted

standing waves are the superposition of identical waves traveling left and right

only standing waves which meet boundary conditions can exist - for example, the boundary conditions on a string are that both ends are nodes.

When two overlapping waves have crests on top of crests, constructive interference occurs. When crests are on top of troughs, destructive interference occurs.

Sound is a longitudinal wave. Pressure and displacement both obey wave equations.

The boundary conditions on standing waves give wavelength. If the velocity is known, frequency can be determined.

In organ pipes, the fipple is open → pressure node, displacement antinode. A closed end has opposite conditions.

When a source and listener are approaching, the frequency is raised. When receding, the frequency is lowered. Be able to use the general Doppler shift equation. - The velocity of sound with respect to the medium is independent of the motion of the source or listener.

A shock wave is created when an object exceeds the speed of sound. Know how to do the geometry.

When two sources of sound of the same amplitude and nearly the same pitch are heard together, the ear hears the average frequency with (beats) pulses at the difference of the frequencies.

The overtones of a drum head are not harmonics.

The timbre of a sound is produced primarily by transients and overtones.

IV. Equations to Memorize

wave equation

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$

velocity of a wave on a string

$$v = \sqrt{\frac{T}{\mu}}$$

traveling wave: $y(x) = A\sin(kx \pm \omega t + \phi)$

standing wave: $y(x) = A\sin(kx)\sin(\omega t)$ (for appropriate boundary conditions)

spherical (3-dimensional) wave: $y(x) = \frac{A_1}{r}\sin(kx \pm \omega t + \phi)$

Conditions for constructive and destructive interference

$$d_2 - d_1 = n\lambda \rightarrow \text{constructive}, \quad d_2 - d_1 = (n + \tfrac{1}{2})\lambda \rightarrow \text{destructive}$$

Sound intensity level. If the sound intensity is twice as large, add 3 dB. If it is 10 times as large, add 10 dB.

$$\beta = 10\log\left(\frac{I}{I_0}\right).$$

Sample Questions

Equations you will be given.

Conceptual Questions

1. Two waves have the same frequency, amplitude, and direction of travel; however, they have a phase difference of 2π. When they are added, the result is

A. A wave with twice the frequency of the original wave.

B. A wave with twice the amplitude of the original wave.

C. A wave with twice the wavelength of the original wave.

D. Nothing.

E. None of the above

2. Oscillatory motion always results from systems where there is 1) there is a "force" which tries to restore the system to its equilibrium state and (2) an "inertia" which tends to carry the system past equilibrium. (Depending on the system, these quantities may not represent an actual force and inertia, hence the quotation marks.) On a stretched string:

A. The "force" is gravity and the "inertia" is the interatomic force in the string.

B. The "force" is tension and the "inertia" is the string's mass.

C. The "force" is tension and the "inertia" is gravity.

D. The "force" is gravity and the "inertia" is tension.

E. None of the above

3. Which statement about stringed musical instruments is NOT true?

A. Lower pitched notes often have heavier strings than higher pitched notes.

B. Lower pitched notes often have longer strings than higher pitched notes.

C. Pitch can be changed by adjusting the tension of the string.

D. Waves on strings are always sine functions of a single frequency.

E. All of the above are true.

Problems

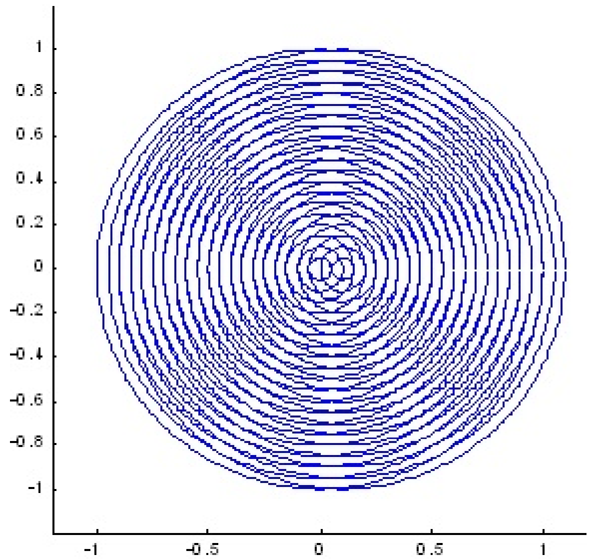
4. Two trains are approaching each other on the same track. They are each traveling at the same speed. Each train sounds its warning whistle, a 400 Hz tone. The velocity of sound in the air is 330 m/s.

(a) If each engineer hears the whistle of the other train at 480 Hz, what is the speed of each train?

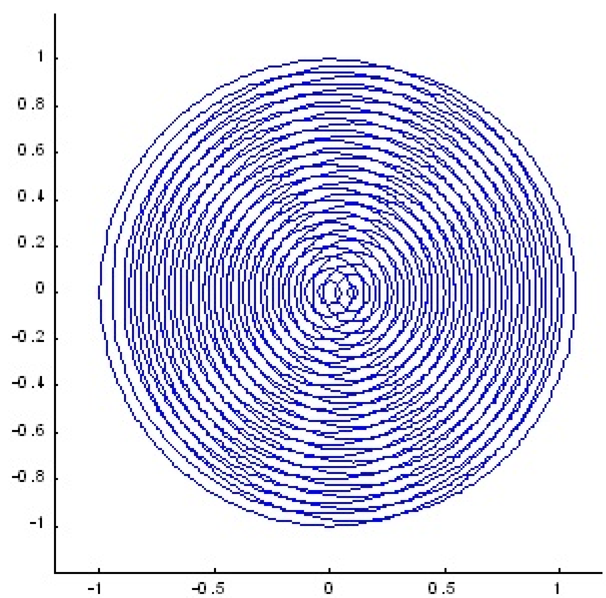
(b) If the trains are traveling at different speeds, which engineer will hear the higher pitch? Justify your answer. (Hint: It may be easier if you think of extreme cases.)

(c) An observer standing on the ground is **behind** one train. What frequencies does he hear for each whistle?

5. (a) Moiré patterns can be used to described the interference of two point sources emitting identical waves in phase with each other. The blue lines represent wave crests. Below is a typical pattern. Show regions of constructive and destructive interference.



(b) Describe what is different about the figure below compared to the figure of part (a).



Answers

Conceptual Questions
1. *B* 2. *B* 3. *D*

Problems
4. (a)

$$f' = f\frac{v+v_o}{v-v_s} = f\frac{v+v_t}{v-v_t}$$
$$(v-v_t)f' = (v+v_t)f$$
$$v(f'-f) = v_t(f'+f)$$
$$v_t = v\frac{f'-f}{f'+f}$$
$$v_t = 330\,\text{m/s}\times\frac{480-400}{480+400} = 30\,\text{m/s}$$

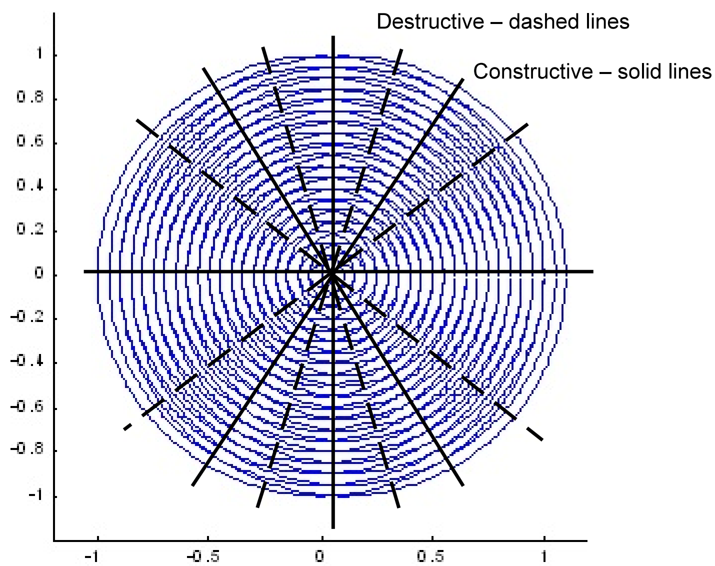
(b) *When the source is moving near the speed of sound and the observer is at rest, the pitch approaches infinity. As the observer moves near the speed of sound with source at rest, the pitch doubles. In general, then, the more slowly moving train hears the higher pitch.*
(c) *For the train going away from the observer:*

$$f' = f\frac{v}{v+v_t}$$
$$f' = 400\,\text{Hz}\times\frac{330}{330+30} = 367\,\text{Hz}$$

For the train approaching the observer:

$$f' = f\frac{v}{v-v_t}$$
$$f' = 400\,\text{Hz}\times\frac{330}{330-30} = 440\,\text{Hz}$$

5. (a)



(b)*The two sources are producing sound out of phase (as easily seen by comparing the inner circles). The regions of constructive and destructive interference are therefore reversed.*