Student #: ____________________________ Student Name: ___________________________________

AP PHYSICS 1: MECHANICAL WAVES AND SOUND WAVES

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

Note: To simplify calculations, you may use $g = 10\,\text{m/s}^2$ in all problems.

1. Which of the following is an example of a longitudinal wave?

   (A) Water wave ← both transverse + longitudinal
   (B) Microwave ← EM waves
   (C) Sound wave
   (D) Radio wave ← transverse
   (E) X-ray

   C

2. Which of the following distances describes the amplitude of a wave?

   ~~(A)~~ Crest to trough
   ~~(B)~~ Crest to crest
   ~~(C)~~ Trough to trough
   ~~(D)~~ Top of crest to bottom of trough
   (E) Crest to equilibrium position

   E

3. A wave has a frequency of 100 Hz. What is the period of the wave?

   $T = \frac{1}{f} = \frac{1}{100}$

   (A) 0.5 s
   (B) 0.01 s
   (C) 0.1 s
   (D) 1 s
   (E) 100 s

   B

4. A wave has a frequency of 100 Hz and a wavelength of 1 m. What is the speed of the wave?

   ← f λ ↗

   $v = f\lambda$

   (A) 0.01 m/s
   (B) 1 m/s
   (C) 10 m/s
   (D) 100 m/s
   (E) 1000 m/s

   D

5. Which of the following quantities remains constant as a mechanical wave travels from one type of spring into another?

   (A) Frequency
   ~~(B)~~ Wavelength ← depends on medium
   ~~(C)~~ Speed
   ~~(D)~~ Amplitude x ← energy is reflected and transmitted
   ~~(E)~~ Spring constant ← cannot guarantee this

   frequency depends on the source only

6. A jackhammer operator wears a set of protective headphones. Through the headphones, a sound wave is broadcast that is 180° out of phase with the jackhammer sound wave. The result is that he does not hear the sound of the jackhammer. These two sound waves are an example of which of the following?

   (A) Standing wave
   (B) Transverse wave
   (C) Destructive interference
   (D) Constructive interference
   (E) Doppler effect

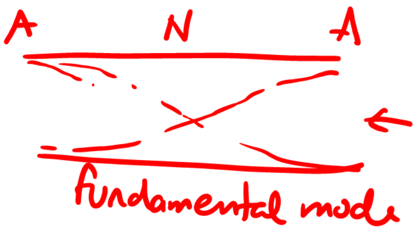
   C

7. Half of a sound wave forms in a 0.500 m open tube when the fundamental frequency is played. What is this fundamental frequency when the speed of sound is 343 m/s?

   ← $\lambda = 1\,\text{m}$

   (A) 34 Hz
   (B) 86 Hz
   (C) 172 Hz
   (D) 343 Hz
   (E) 686 Hz

   D



$v = f\lambda$ $f = \frac{v}{\lambda} = \frac{343}{1}$

8. Two waves have the same frequency. What other characteristic must be the same for these waves?

   ~~(A)~~ Speed
   (B) Period ← $T = \frac{1}{f}$
   ~~(C)~~ Amplitude
   ~~(D)~~ Intensity
   ~~(E)~~ Wavelength

   B

9. A child dips her finger repeatedly into the water to make waves. If she dips her finger more frequently, the wavelength ____ and the speed ____.

   ~~(A)~~ Increases; decreases
   ~~(B)~~ Decreases; increases
   (C) Increases; stays the same
   (D) Decreases; stays the same
   ~~(E)~~ Stays the same; increases

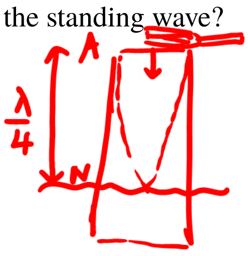
   $v = f\lambda$ ↑ ↓

   D

10. A 0.50 m tube is placed in a bucket of water. The tube can be moved up and down to vary the length of the column of air inside, and the temperature of the air is 20 °C, which corresponds to a sound speed of 343 m/s. A 440 Hz tuning fork is struck and placed over the mouth of the tube. The tube is moved up and down until the first resonance can be heard. What is the length of the column of air inside the tube when one antinode and one node form in the standing wave?

    (A) 0.09 m
    (B) 0.19 m
    (C) 0.27 m
    (D) 0.38 m
    (E) 0.5 m

    B



$v = f\lambda$

$\lambda = \frac{v}{f} = \frac{343}{440}$

$\frac{\lambda}{4} = 0.19488\ldots$

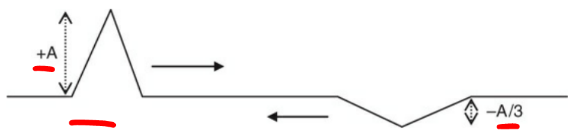
11. A 440 Hz and a 444 Hz tuning fork are struck simultaneously. What is the beat frequency that you hear?

    (A) 1 Hz
    (B) 2 Hz
    (C) 4 Hz
    (D) 221 Hz
    (E) 442 Hz

    $|f_1 - f_2|$

    $= 444 - 440$

Questions 12–14 use the following figure:



12. Two waves are traveling on a string. The directions and amplitude of each wave are shown in the figure. When the two waves meet, what will be the amplitude of the resulting wave?
   (A) $-4A/3$
   (B) $-2A/3$
   (C) 0
   (D) $2A/3$
   (E) $4A/3$

D

13. The figure depicts which of the following phenomena?
   (A) Standing wave
   (B) Transverse wave
   (C) Destructive interference
   (D) Constructive interference
   (E) Doppler effect

C

14. After the waves interact, what will happen?
   (A) One wave ($2A/3$) will travel to the right.
   (B) One wave ($-2A/3$) will travel to the left.
   (C) There will be no more waves.
   (D) One wave ($+A$) will travel to the right, while one wave ($-A/3$) will travel to the left.
   (E) One wave ($-A$) will travel to the right, while one wave ($+A/3$) will travel to the left.

D

15. Which of the following measurements is used to find the wavelength?
   (A) Crest to zero displacement
   (B) Crest to trough
   (C) Trough to zero displacement
   (D) Trough to crest
   (E) Crest to crest

E

high intensity → high amplitude

low frequency

16. What is true about a loud sound with a low pitch?
   (A) It travels faster than a soft sound.
   (B) It travels slower than a high-pitch sound.
   (C) It has large amplitude and low frequency.
   (D) It has small amplitude and high frequency.
   (E) It has small amplitude and low frequency.

17. As a wave is formed, what is the relationship between the wavelength and frequency?
   (A) Linearly related and directly proportional
   (B) Linearly related but not directly proportional
   (C) Inversely proportional
   (D) Parabolic
   (E) Exponential

C

$v = f\lambda$

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

18. The sound from a loudspeaker vibrating at 256 Hz interferes with a trumpet vibrating at 252 Hz. What sound results?
   (A) A 254-Hz pitch with a 4-Hz beat frequency
   (B) A 4-Hz pitch with a 254-Hz beat frequency
   (C) A melodic chord
   (D) Two distinct pitches
   (E) A resonance with a frequency of 308 Hz

A

19. Which of the following is observed as a constantly moving source of sound passes a receiver that is at rest?
   (A) The frequency and the speed increase.
   (B) The frequency decreases, and the speed increases.
   (C) The frequency decreases, and the speed stays the same.
   (D) The frequency and the speed stay the same.
   (E) The frequency increases, and the speed decreases.

C

20. What is observed when sound beats occur?
   (A) A rhythmic change in the pitch of the sound
   (B) A regular increase and decrease in the speed of the sound
   (C) An increase in frequency of the sound
   (D) A dramatic growth in amplitude of the sound
   (E) A sound that gets louder and softer at regular intervals

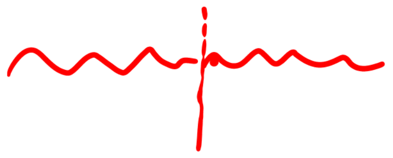
E

21. Which of the following best describes a wave?
   (A) pattern resembling a sine wave
   (B) An object that oscillates back and forth at a characteristic frequency
   (C) A disturbance that carries energy and momentum from one place to another with the transfer of mass
   (D) A disturbance that carries energy and momentum from one place to another without the transfer of mass
   (E) An oscillating electric and magnetic field that cannot travel through a vacuum

22. Which of the following are true about sound waves?
   (A) Their speed increases slightly with temperature.
   (B) They travel faster than light waves.
   (C) Their speed gets greater as the pitch of the sound increases.
   (D) They travel faster in water than in steel.
   (E) They can travel in the vacuum of space.

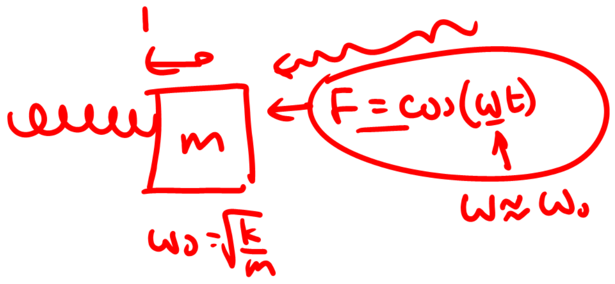
23. The speed of a sound wave depends on which of the following?
   (A) The loudness and pitch of the sound
   (B) The intensity of the vibration
   (C) The frequency of the source of vibration
   (D) The motion of the observer
   (E) The type of medium

24. Which of the following may NOT occur when a single wave hits a boundary between one medium and another?
   (A) It reflects back into the original medium.
   (B) It transmits into the new medium.
   (C) Its frequency changes.
   (D) Its wavelength decreases.
   (E) Some of its energy is absorbed as thermal energy.



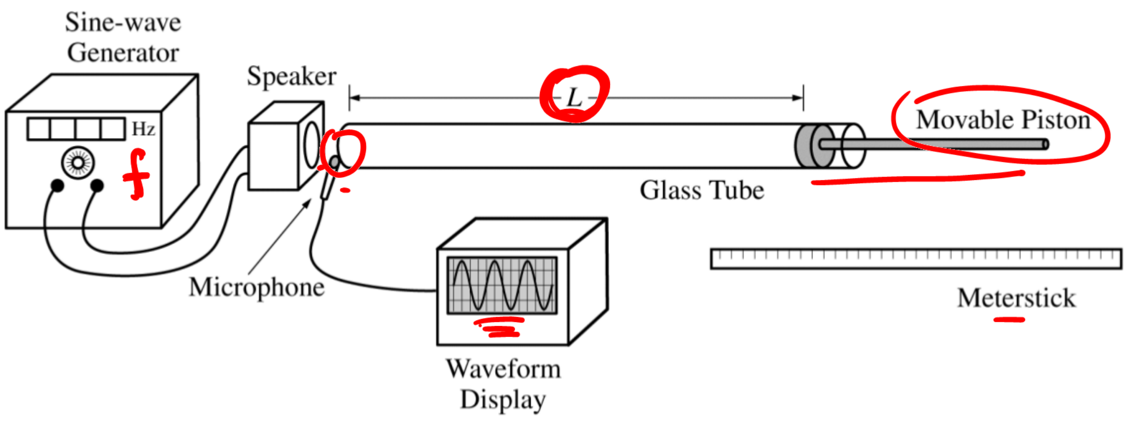
25. Which of the following are examples of resonance?
   (A) A low frequency beat is detected when two tuning forks are played together.
   (B) A high frequency is detected when a moving object approaches an observer.
   (C) A tuning fork starts vibrating when an identical tuning fork vibrates next to it.
   (D) Two waves combine to form a wave with a larger amplitude.

C



AP PHYSICS 1: MECHANICAL WAVES AND SOUND WAVES
SECTION II
4 Questions

Directions: Answer all questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.

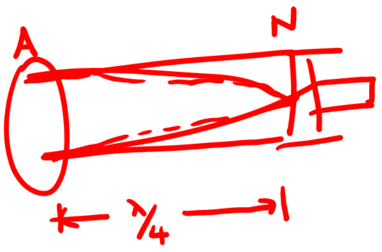


1. You are given the apparatus represented in the figure above. A glass tube is fitted with a movable piston that allows the indicated length L to be adjusted. A sine-wave generator with an adjustable frequency is connected to a speaker near the open end of the tube. The output of a microphone at the open end is connected to a waveform display. You are to use this apparatus to measure the speed of sound in air.

   (a) Describe a procedure using the apparatus that would allow you to determine the speed of sound in air. Clearly indicate what quantities you would measure and with what instrument each measurement would be made. Represent each measured quantity with a different symbol.

   (b) Using the symbols defined in part (a), indicate how your measurements can be used to determine an experimental value of the speed of sound.

   (c) A more accurate experimental value can be obtained by varying one of the measured quantities to obtain multiple sets of data. Indicate one quantity that can be varied, and describe how a graph of the resulting data could be used to determine the speed of sound. Clearly identify independent and dependent variables, and indicate how the slope of the graph relates to the speed of sound.



b) $v = f(\lambda) = \frac{fL}{4}$

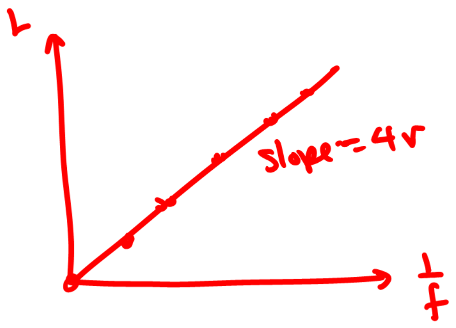
c) $v = \frac{fL}{4}$

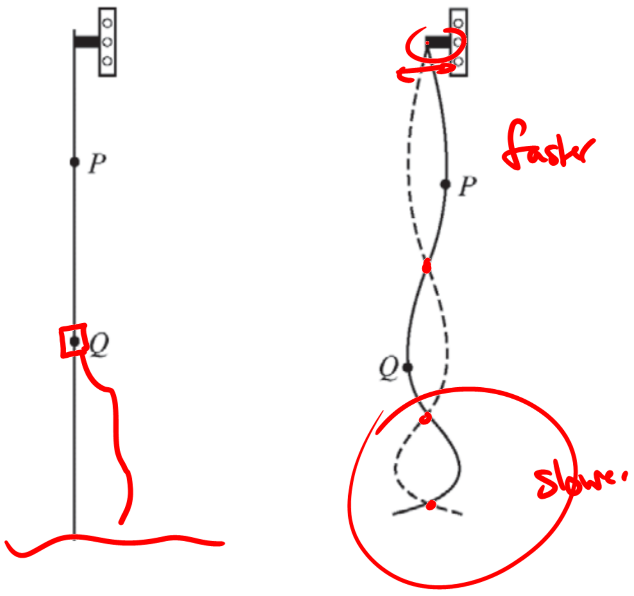
$4v = fL$

independent variable

dependent variable

$\underbrace{L}_{y} = \underbrace{4v}_{m}\underbrace{\left(\frac{1}{f}\right)}_{x}$

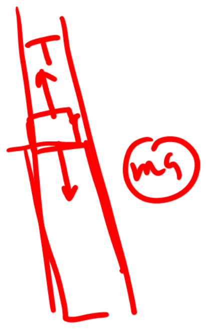




2. (Suggested time 13 minutes) The figure above on the left shows a uniformly thick rope hanging vertically from an oscillator that is turned off. When the oscillator is on and set at a certain frequency, the rope forms the standing wave shown above on the right. P and Q are two points on the rope.

   (a) The tension at point P is greater than the tension at point Q. Briefly explain why.

   (b) A student hypothesizes that increasing the tension in a rope increases the speed at which waves travel along the rope. In a clear, coherent paragraph-length response that may also contain figures and/or equations, explain why the standing wave shown above supports the students hypothesis.



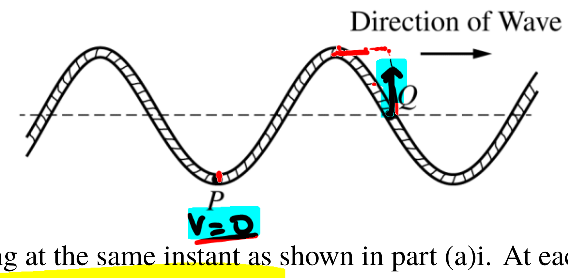
- nodes are closer together near the bottom of the rope, where the tension is lower
- nodes closer → $v = f\lambda$ means shorter wavelength.
  → speed of the wave is slower.

∴ ~~tens~~ higher tension ⇒ faster speed
lower tension → slower speed.

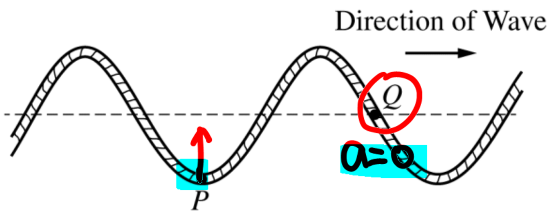
3. (Suggested time 13 minutes) A transverse wave travels to the right along a string.

(a) Two dots have been painted on the string. In the diagrams below, those dots are labeled P and Q.

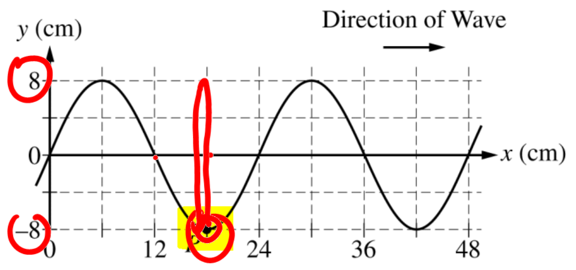
i. The figure below shows the string at an instant in time. At the instant shown, dot P has maximum displacement and dot Q has zero displacement from equilibrium. At each of P and Q, draw an arrow indicating the direction of the instantaneous velocity of that dot. If either dot has zero velocity, write "$v = 0$" next to the dot.



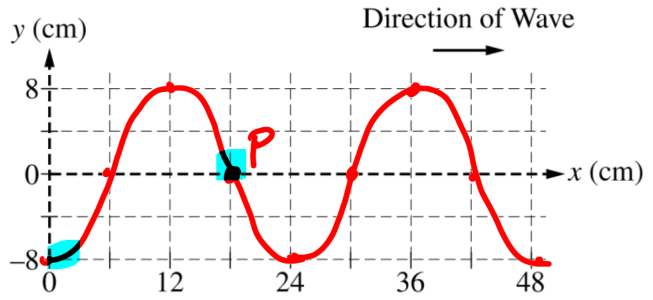
ii. The figure below shows the string at the same instant as shown in part (a)i. At each of P and Q, draw an arrow indicating the direction of the instantaneous acceleration of that dot. If either dot has zero acceleration, write "$a = 0$" next to the dot.



The figure below represents the string at time $t = 0$, the same instant as shown in part (a) when dot P is at it maximum displacement from equilibrium. For simplicity, dot Q is not shown.



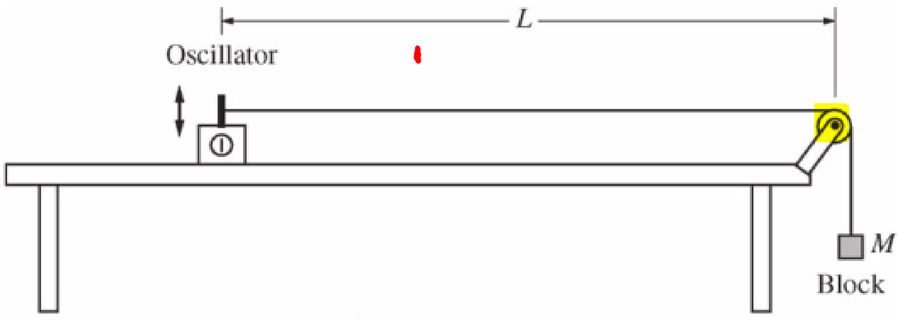
(b) i. On the grid below, draw the string at a later time $t = T/4$, where T is the period of the wave.



ii. On your drawing above, draw a dot to indicate the position of dot P on the string at time $t = T/4$ and clearly label the dot with the letter P.

(c) Now consider the wave at time $t = T$. Determine the distance traveled (not the displacement) by dot P between times $t = 0$ and $t = T$.

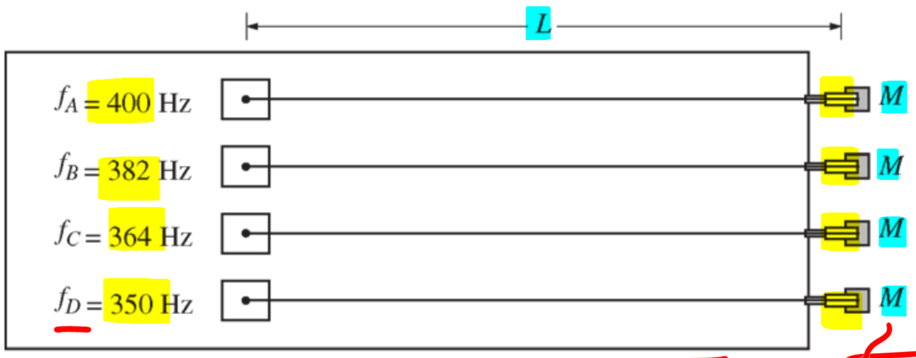
32cm



Side View

4. (7 points, suggested time 13 minutes) The figure above shows a string with one end attached to an oscillator and the other end attached to a block. The string passes over a massless pulley that turns with negligible friction. Four such strings, A, B, C, and D, are set up side by side, as shown in the diagram below. Each oscillator is adjusted to vibrate the string at its fundamental frequency f. The distance between each oscillator and pulley L is the same, and the mass M of each block is the same. However, the fundamental frequency of each string is different.

$L = \lambda/2$



Top View

$v = \sqrt{\frac{F_T L}{m}} = \sqrt{\frac{Mg\lambda}{2m}}$ mass of string.

The equation for the velocity v of a wave on a string is $v = \sqrt{\frac{F_T}{m/L}}$, where F_T is the tension of the string and m/L is the mass per unit length (linear mass density) of the string.

(a) What is different about the four strings shown above that would result in their having different fundamental frequencies? Explain how you arrived at your answer.

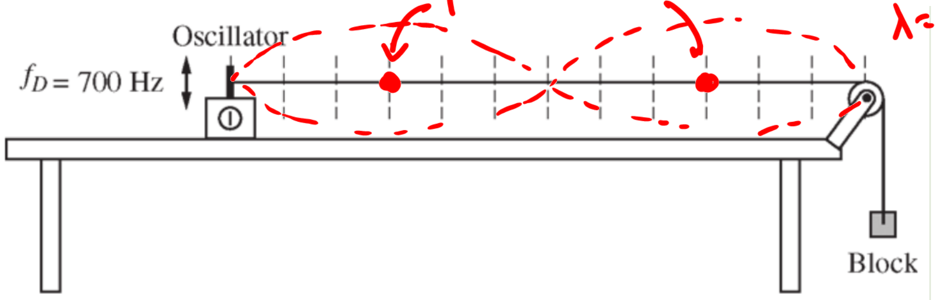
(b) A student graphs frequency as a function of the inverse of the linear mass density. Will the graph be linear? Explain how you arrived at your answer.

(c) The frequency of the oscillator connected to string D is changed so that the string vibrates in its second harmonic. On the side view of string D below, mark and label the points on the string that have the greatest average vertical speed.

antinode

points that have greatest speed.

$\lambda = L$



Side View

a) $v = f\lambda = \sqrt{\frac{Mg\lambda}{2m}} \rightarrow f^2\lambda^2 = \frac{Mg\lambda}{2m} \rightarrow f^2\lambda = \frac{Mg}{2m}$

heavier the mass of the string → lower frequency.

b) $v = \sqrt{\frac{F_T}{\mu}} = f\lambda = f\frac{L}{2}$ $\qquad \frac{F_T}{\mu} = \frac{fL}{2}$ → relationship is inverse.

linear mass density

$v = f\lambda$