2019

AP® CollegeBoard

AP® Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

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Free Response Question 5

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General Notes About 2019 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. The requirements that have been established for the paragraph-length response in Physics 1 and Physics 2 can be found on AP Central at https://secure-media.collegeboard.org/digitalServices/pdf/ap/paragraph-length-response.pdf.

3. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

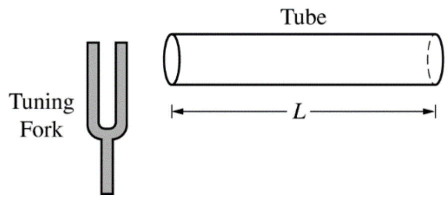
4. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth 1 point, and a student's solution embeds the application of that equation to the problem in other work, the point is still awarded. However, when students are asked to derive an expression, it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections — Student Presentation" in the *AP Physics; Physics C: Mechanics, Physics C: Electricity and Magnetism Course Description* or "Terms Defined" in the *AP Physics 1: Algebra-Based Course and Exam Description* and the *AP Physics 2: Algebra-Based Course and Exam Description*.

5. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but the use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

6. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 5

7 points



A tuning fork vibrating at 512 Hz is held near one end of a tube of length L that is open at both ends, as shown above. The column of air in the tube resonates at its fundamental frequency. The speed of sound in air is $340\ \text{m/s}$.

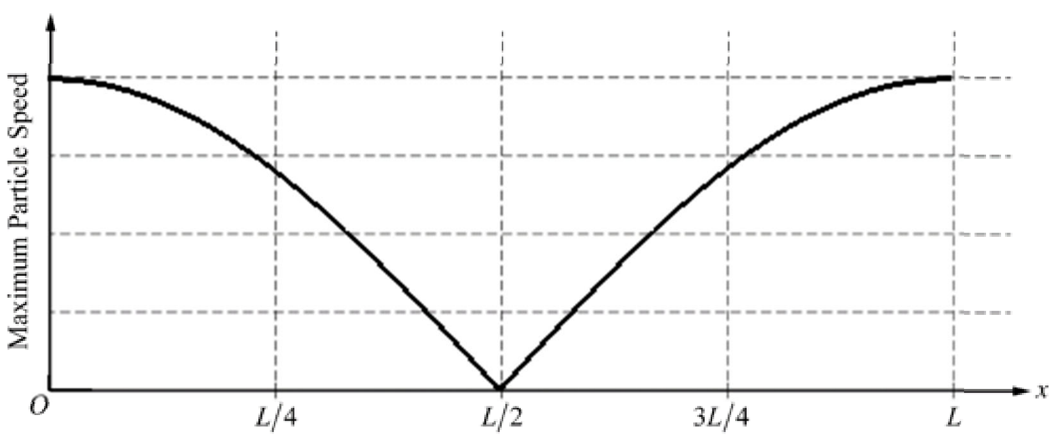
(a) LO 6.D.3.4, SP 1.2; LO 6.D.4.2, SP 2.2
2 points

Calculate the length L of the tube.

For using $\lambda = v/f$		1 point
$\lambda = (340\ \text{m/s})/(512\ \text{Hz}) = 0.66\ \text{m}$		
For a length that is half of the calculated wavelength, with units		1 point
$L = \lambda/2 = 0.33\ \text{m}$		

(b) LO 6.A.1.2, SP 1.2; LO 6.D.3.2, SP 6.4; LO 6.D.3.4, SP 1.2; LO 6.D.4.2, SP 2.2
3 points

The column of air in the tube is still resonating at its fundamental frequency. On the axes below, sketch a graph of the maximum speed of air molecules as they oscillate in the tube, as a function of position x, from $x = 0$ (left end of tube) to $x = L$ (right end of tube). (Ignore random thermal motion of the air molecules.)



For a curve with a node (zero) at $L/2$		1 point
For a curve with maxima at 0, L, and no other points		1 point
For a nonhorizontal curve that is symmetric around $L/2$ and nonnegative everywhere		1 point

Question 5 (continued)

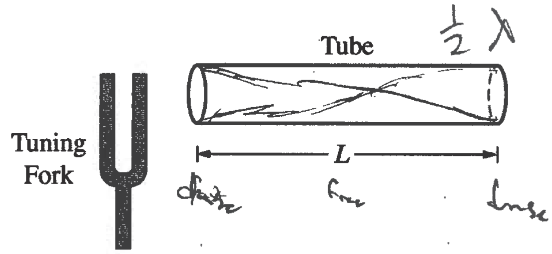
(c) LO 6.D.3.4, SP 1.2; LO 6.D.4.2, SP 2.2)
2 points

The right end of the tube is now capped shut, and the tube is placed in a chamber that is filled with another gas in which the speed of sound is $1005\ \text{m/s}$. Calculate the new fundamental frequency of the tube.

Correct answer: 757 Hz		
For an indication that the fundamental wavelength is $4L$		1 point
For substituting the new sound speed in $v = \lambda f$		1 point

Learning Objectives

LO 6.A.1.2: The student is able to describe representations of transverse and longitudinal waves. [See Science Practice 1.2]
LO 6.D.3.2: The student is able to predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. [See Science Practice 6.4]
LO 6.D.3.4: The student is able to describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region. [See Science Practice 1.2]
LO 6.D.4.2: The student is able to calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments. [See Science Practice 2.2]



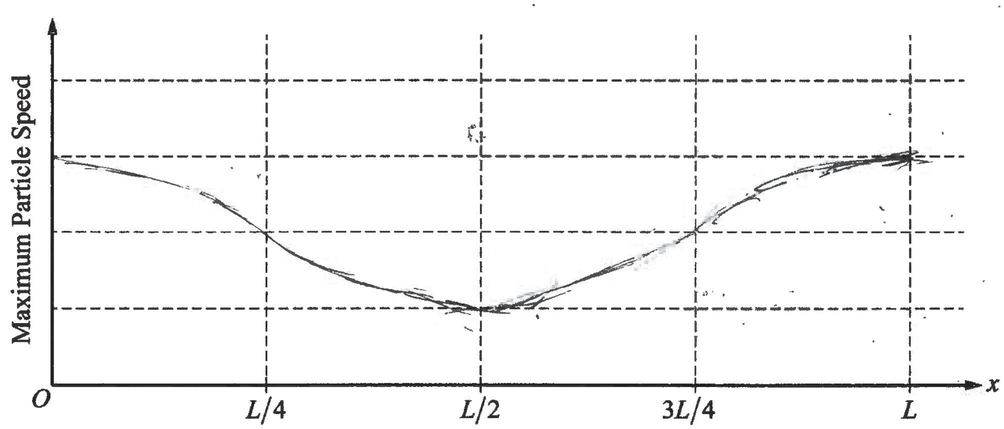
5. (7 points, suggested time 13 minutes)

A tuning fork vibrating at 512 Hz is held near one end of a tube of length L that is open at both ends, as shown above. The column of air in the tube resonates at its fundamental frequency. The speed of sound in air is 340 m/s.

(a) Calculate the length L of the tube.

$L = \frac{1}{2}\lambda \quad \lambda = 2L \quad v = \lambda f \quad v = 2Lf \quad \frac{v}{2f} = L = \frac{340}{512 \cdot 2} = 0.33 \text{ m}$

(b) The column of air in the tube is still resonating at its fundamental frequency. On the axes below, sketch a graph of the maximum speed of air molecules as they oscillate in the tube, as a function of position x, from $x = 0$ (left end of tube) to $x = L$ (right end of tube). (Ignore random thermal motion of the air molecules.)

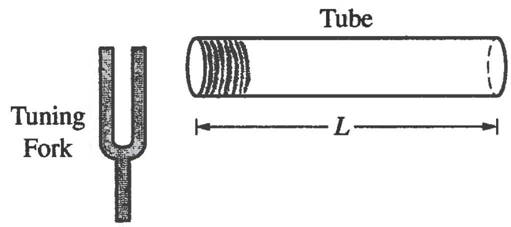


(c) The right end of the tube is now capped shut, and the tube is placed in a chamber that is filled with another gas in which the speed of sound is 1005 m/s. Calculate the new fundamental frequency of the tube.

$\frac{1}{4}\lambda = L \quad \lambda = 4L$

$v = \lambda f \quad v = 4Lf$

$\frac{v}{4L} = f = \frac{1005}{4 \cdot (0.33)} = 761.36 \text{ Hz}$



5. (7 points, suggested time 13 minutes)

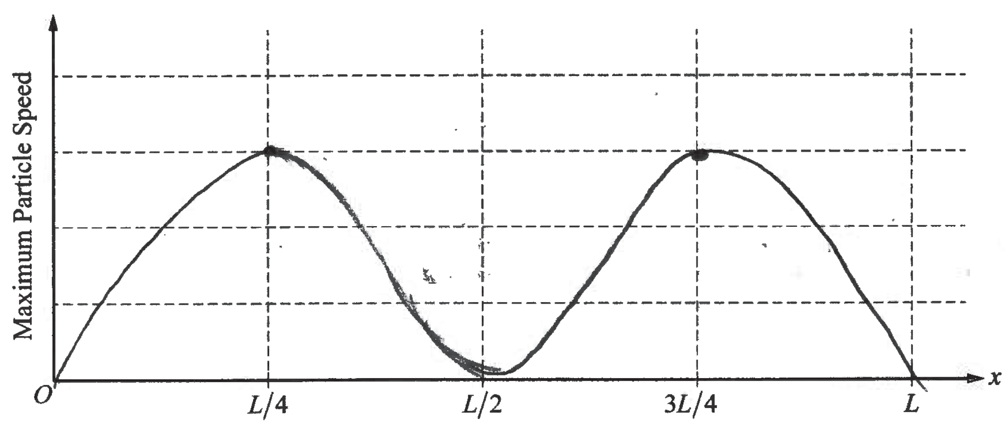
A tuning fork vibrating at 512 Hz is held near one end of a tube of length L that is open at both ends, as shown above. The column of air in the tube resonates at its fundamental frequency. The speed of sound in air is 340 m/s.

(a) Calculate the length L of the tube.

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

$\lambda = \frac{340 \frac{m}{s}}{512 Hz}$ $\lambda = 0.664 m$

(b) The column of air in the tube is still resonating at its fundamental frequency. On the axes below, sketch a graph of the maximum speed of air molecules as they oscillate in the tube, as a function of position x, from $x = 0$ (left end of tube) to $x = L$ (right end of tube). (Ignore random thermal motion of the air molecules.)



(c) The right end of the tube is now capped shut, and the tube is placed in a chamber that is filled with another gas in which the speed of sound is 1005 m/s. Calculate the new fundamental frequency of the tube.

$V = 1005 \frac{m}{s}$

$\lambda = 0.664 m$

$f = \frac{V}{\lambda} = \frac{1005}{0.664}$

$f = 1512.87 Hz$

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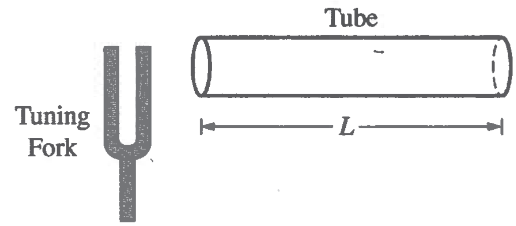


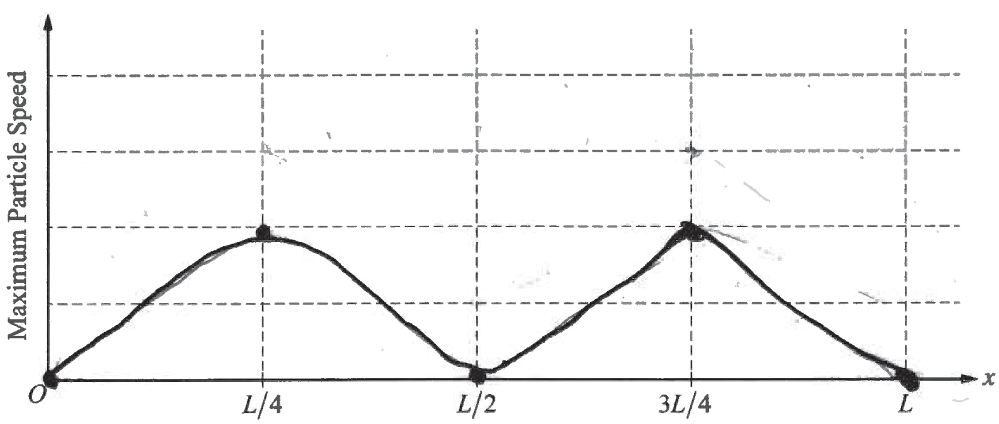
5. (7 points, suggested time 13 minutes)

A tuning fork vibrating at 512 Hz is held near one end of a tube of length L that is <u>open</u> at both ends, as shown above. The column of air in the tube resonates at its fundamental frequency. The speed of sound in air is 340 m/s.

(a) Calculate the length L of the tube.

a = 340
H = 512
$L = \frac{512}{340} = 1.5$

(b) The column of air in the tube is still resonating at its fundamental frequency. On the axes below, sketch a graph of the maximum speed of air molecules as they oscillate in the tube, as a function of position x, from $x = 0$ (left end of tube) to $x = L$ (right end of tube). (Ignore random thermal motion of the air molecules.)



(c) The right end of the tube is now capped shut, and the tube is placed in a chamber that is filled with another gas in which the speed of sound is 1005 m/s. Calculate the new fundamental frequency of the tube.

$1.5 = \frac{f}{1005}$

$f = (1.5)(1005)$
$= 1507.5$

GO ON TO THE NEXT PAGE.

Question 5

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

The responses to this question were expected to demonstrate the following:

- An understanding of the resonant frequencies of tubes open at both ends and open at one end.
- Use of the mathematical relationship between frequency and wavelength.
- Use of the mathematical relationship between length of the tube and wavelength.
- Understanding where nodes and antinodes exist in a tube as well as the peak speed of particles at nodes and antinodes.

Sample: 5A
Score: 6

In part (a) both points were earned. The equation $v = f\lambda$ is used correctly, and the tube length is half of the calculated wavelength, with units. In part (b) 2 of 3 points were earned. One point was earned for the maxima located at 0 and L only. One point was earned for a nonhorizontal curve with symmetry around $L/2$. The response did not earn 1 point because the minimum drawn at $L/2$ is not a node (zero). In part (c) both points were earned for indicating that the fundamental wavelength is $4L$ and for substituting the new sound speed $v = 1005\ \text{m/s}$.

Sample: 5B
Score: 4

In part (a) 1 of 2 points was earned for using the equation $v = f\lambda$ correctly. One point was not earned because the tube length is not calculated. In part (b) 2 of 3 points were earned. One point was earned for drawing a node at $L/2$, and 1 point was earned for a nonhorizontal curve with symmetry around $L/2$. One point was not earned because the maxima are not located at 0 and L. In part (c) 1 of 2 points was earned for substituting the new sound speed of $v = 1005\ \text{m/s}$ into $f = v/\lambda$. The response did not earn 1 point because it does not indicate that the fundamental wavelength is $4L$.

Sample: 5C
Score: 2

In part (a) neither of the 2 points were earned. The equation $v = f\lambda$ is not clearly indicated and seems to be used incorrectly, and there is no indication that the tube length is half of the wavelength. In part (b) 2 of 3 points were earned. One point was earned for drawing a node at $L/2$, and one point was earned for a nonhorizontal curve with symmetry around $L/2$. One point was not earned because the maxima are not located at 0 and L. In part (c) neither of the 2 points were earned. There is no indication that $4L$ is the fundamental wavelength, and the new sound speed is not substituted into $v = f\lambda$ or an equivalent equation.