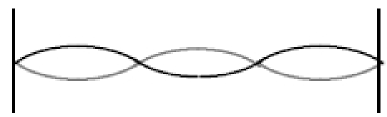
AP Physics Multiple Choice Practice –Waves and Optics

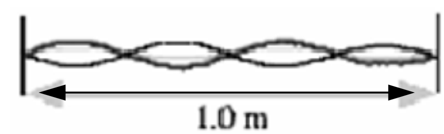
SECTION A – Waves and Sound

1. A string is firmly attached at both ends. When a frequency of 60 Hz is applied, the string vibrates in the standing wave pattern shown. Assume the tension in the string and its mass per unit length do not change. Which of the following frequencies could NOT also produce a standing wave pattern in the string?
   A) 30 Hz B) 40 Hz C) 80 Hz D) 180 Hz

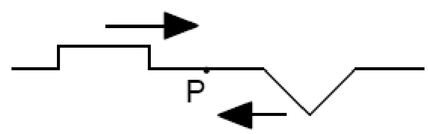


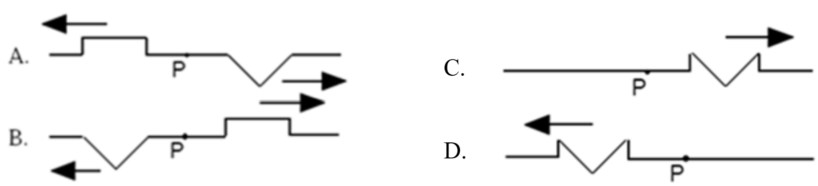
2. If the frequency of sound wave is doubled, the wavelength:
   A) halves and the speed remains unchanged.
   B) doubles and the speed remains unchanged.
   C) halves and the speed halves.
   D) doubles and the speed doubles.

3. The standing wave pattern diagrammed to the right is produced in a string fixed at both ends. The speed of waves in the string is 2 m/s. What is the frequency of the standing wave pattern?
   A) 0.25 Hz B) 1 Hz C) 2 Hz D) 4 Hz



4. Two waves pulses approach each other as seen in the figure. The wave pulses overlap at point P. Which diagram best represents the appearance of the wave pulses as they leave point P?





5. If the speed of sound in air is 340 m/s, the length of the organ pipe, open at both ends, that can resonate at the fundamental frequency of 136 Hz, would be:
   A) 0.40 m B) 0.80 m C) 1.25 m D) 2.5 m

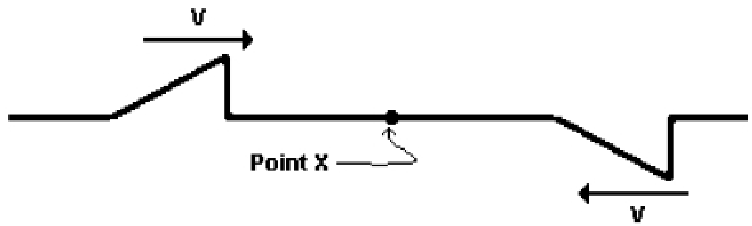
6. As sound travels from steel into air, both its speed and its:
   A) wavelength increase B) wavelength decrease C) frequency increase D) frequency remain unchanged

7. A pipe that is closed at one end and open at the other resonates at a fundamental frequency of 240 Hz. The next lowest/highest frequency it resonates at is most nearly.
   A) 80 Hz B) 120 Hz C) 480 Hz D) 720 Hz

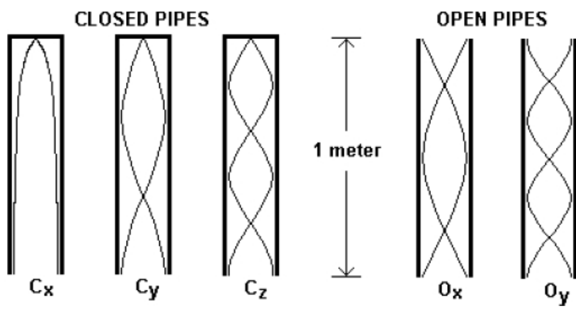
8. Assume that waves are propagating in a uniform medium. If the frequency of the wave source doubles then
   A) the wavelength of the waves halves. B) the wavelength of the waves doubles.
   C) the speed of the waves halves. D) the speed of the waves doubles.

9. Assume the speed of sound is 340 m/s. One stereo loudspeaker produces a sound with a wavelength of 0.68 meters while the other speaker produces sound with a wavelength of 0.65 m. What would be the resulting beat frequency?
   A) 3 Hz B) 23 Hz C) 511.5 Hz D) 11,333 Hz

10. The diagram shows two transverse pulses moving along a string. One pulse is moving to the right and the second is moving to the left. Both pulses reach point x at the same instant. What would be the resulting motion of point x as the two pulses pass each other?

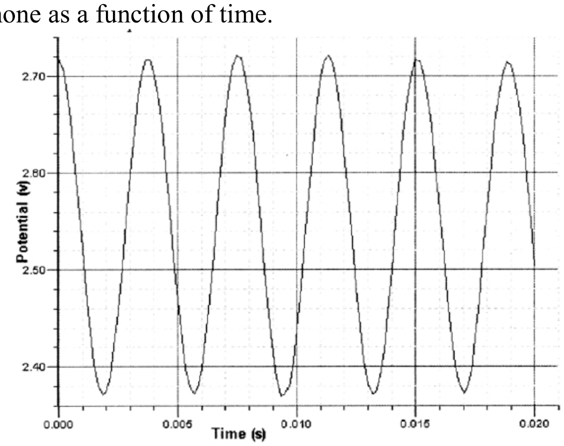


A) down, up, down
B) up then down
C) up, down, up
D) there would be no motion, the pulses cancel one another



11. **Multiple Correct.** The diagrams above represent 5 different standing sound waves set up inside of a set of organ pipes 1 m long Which of the following statements correctly relates the frequencies of the organ pipes shown? Select two answers.
A) C_y is twice the frequency of C_x. B) C_z is five times the frequency of C_x.
C) O_y is twice the frequency of O_x. D) O_x is twice the frequency of C_x.

<u>Questions 12-13:</u> The graph below was produced by a microphone in front of a tuning fork. It shows the voltage produced from the microphone as a function of time.



12. The frequency of the tuning fork is (approximately)
A) 0.004 s B) 0.020 s C) 50Hz D) 250 Hz

13. In order to calculate the speed of sound from the graph, you would also need to know
A) pitch B) wavelength C) frequency D) volume

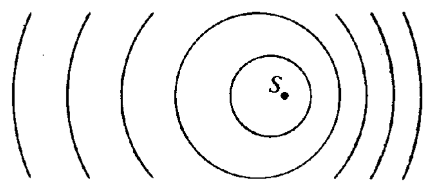
14. A tube is open at both ends with the air oscillating in the 4^{th} harmonic. How many displacement nodes are located within the tube?
A) 2 B) 3 C) 4 D) 5

15. A person vibrates the end of a string sending transverse waves down the string. If the person then doubles the rate at which he vibrates the string while maintaining the same tension , the speed of the waves
A) is unchanged while the wavelength is halved.
B) is unchanged while the wavelength is doubled.
C) doubles while the wavelength doubled.
D) doubles while the wavelength is halved.

16. A tube of length L_1 is open at both ends. A second tube of length L_2 is closed at one end and open at the other end. This second tube resonates at the same fundamental frequency as the first tube. What is the value of L_2 ?
A) $4L_1$ B) $2L_1$ C) L_1 D) ½ L_1

17. For a standing wave mode on a string fixed at both ends, adjacent antinodes are separated by a distance of 20 cm. Waves travel on this string at a speed of 1200 cm/s. At what frequency is the string vibrated to produce this standing wave?
(A) 120 *Hz* (B) 60 *Hz* (C) 40 *Hz* (D) 30 *Hz*

18. What would be the wavelength of the fundamental and first two overtones produced by an organ pipe of length L that is closed at one end and open at the other?
A) L, ½ L, ¼ L B) ½ L, ¼ L, 1/6 L C) 4L, 4/3 L, 4/5 L D) 4L, 2L, L

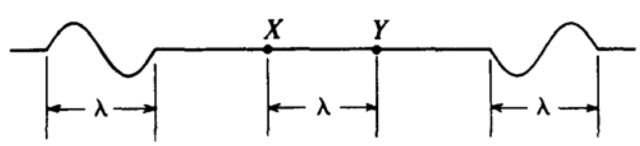


19. A small vibrating object S moves across the surface of a ripple tank producing the wave fronts shown above. The wave fronts move with speed v. The object is traveling in what direction and with what speed relative to the speed of the wave fronts produced?

Direction	Speed
(A) To the right	Equal to v
(B) To the right	Less than v
(C) To the left	Less than v
(D) To the left	Greater than v

20. A vibrating tuning fork sends sound waves into the air surrounding it. During the time in which the tuning fork makes one complete vibration, the emitted wave travels
(A) one wavelength
(B) about 340 meters
(C) a distance directly proportional to the square root of the air density
(D) a distance inversely proportional to the square root of the pressure

21. Two wave pulses, each of wavelength λ, are traveling toward each other along a rope as shown. When both pulses are in the region between points X and Y, which are a distance λ apart, the shape of the rope is



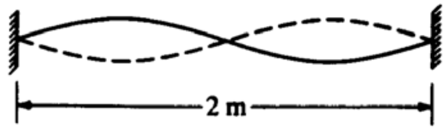
(A) 

(B) 

(C) 

(D) 

Questions 22-23

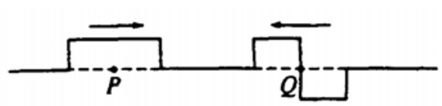


A standing wave of frequency 5 hertz is set up on a string 2 meters long with nodes at both ends and in the center, as shown above.

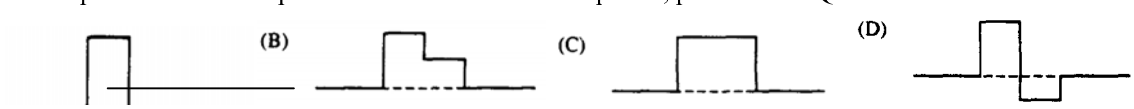
22. The speed at which waves propagate on the string is
A) 0.4 m/s B) 2.5 m/s C) 5 m/s D) 10 m/s

23. The fundamental frequency of vibration of the string is
A) 1 Hz B) 2.5 Hz C) 5 Hz D) 10 Hz

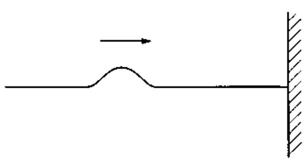
24. **Multiple correct:** In the Doppler Effect for sound waves, factors that affect the frequency that the observer hears include which of the following? Select two answers.
A) the loudness of the sound
B) the speed of the source
C) the speed of the observer
D) the phase angle



25. The figure above shows two wave pulses that are approaching each other. Which of the following best shows the shape of the resultant pulse when the centers of the pulses, points P and Q coincide?

(A)


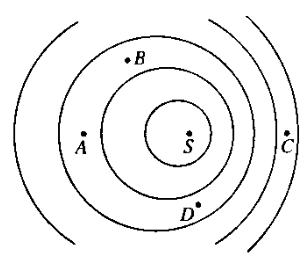
26. **Multiple Correct:** One end of a horizontal string is fixed to a wall. A transverse wave pulse is generated at the other end, moves toward the wall as shown and is reflected at wall. Properties of the reflected pulse include which of the following? Select two answers:



(A) It has a greater speed than that of the incident pulse.
(B) It has a greater amplitude than that of the incident pulse.
(C) It is on the opposite side of the string from the incident pulse.
(D) It has a smaller amplitude than that of the incident pulse.

27. A small vibrating object on the surface of a ripple tank is the source of waves of frequency 20 Hz and speed 60 cm/s. If the source *S* is moving to the right, as shown, with speed 20 cm/s, at which of the labeled points will the frequency measured by a stationary observer be greatest?

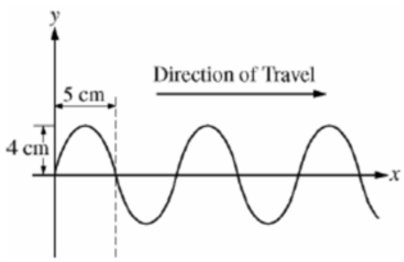
(A) A (B) B (C) C (D) D



28. The frequencies of the first two overtones (second and third harmonics) of a vibrating string are f and 3f/2 .What is the fundamental frequency of this string?
A) f/3 B) f/2 C) f D) 2f

29. **Multiple Correct:** Two fire trucks have sirens that emit waves of the same frequency. As the fire trucks approach a person, the person hears a higher frequency from truck X than from truck Y. Which of the following statements about truck X can be correctly inferred from this information? Select two answers.
A) It is traveling faster than truck Y.
B) It is closer to the person than truck Y.
C) It is speeding up, and truck Y is slowing down.
D) Its wavefronts are closer together than truck Y.

<u>Questions 30-31:</u>



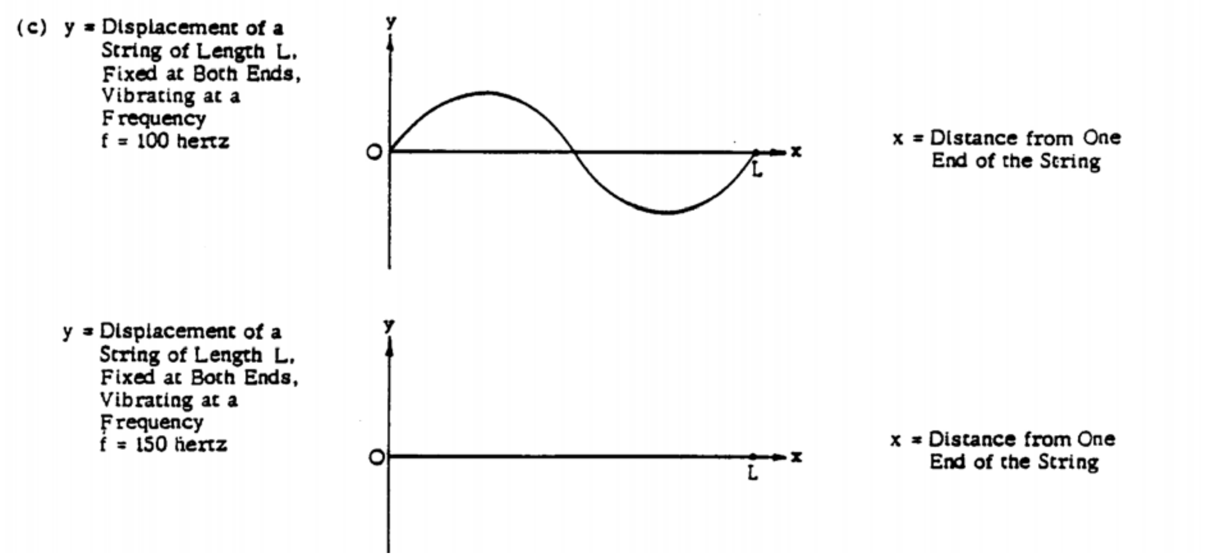
The figure above shows a transverse wave traveling to the right at a particular instant of time. The period of the wave is 0.2 s.

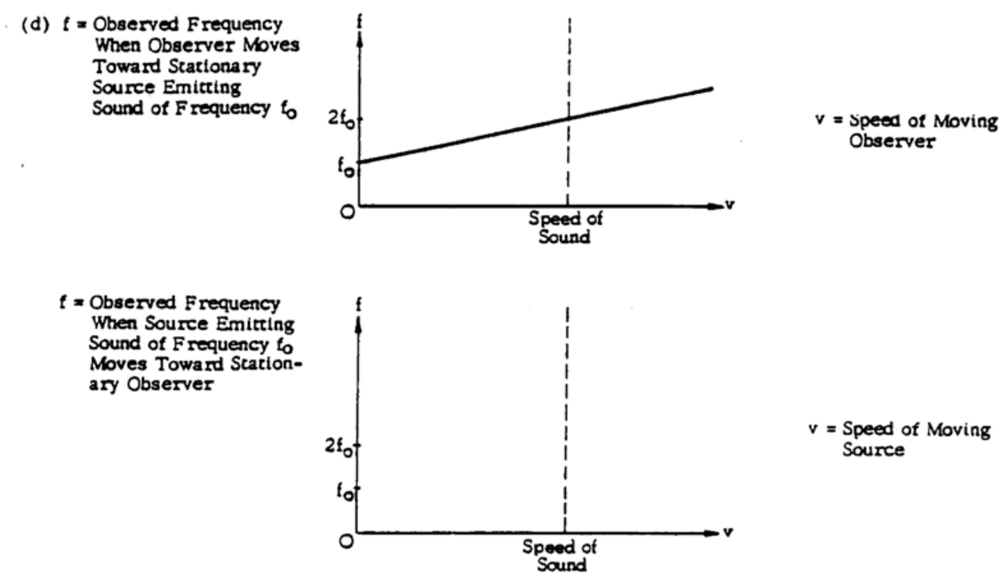
30. What is the amplitude of the wave?
A) 4 cm B) 5 cm C) 8 cm D) 10 cm

31. What is the speed of the wave?
A) 4 cm/s B) 25 cm/s C) 50 cm/s D) 100 cm/s

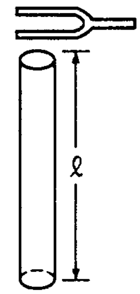
32. **Multiple Correct:** A standing wave pattern is created on a guitar string as a person tunes the guitar by changing the tension in the string. Which of the following properties of the waves on the string will change as a result of adjusting only the tension in the string? Select two answers.
A) the speed of the traveling wave that creates the pattern
B) the wavelength of the standing wave
C) the frequency of the standing wave
D) the amplitude of the standing wave

1980B4. In the graphs that follow, a curve is drawn in the first graph of each pair. For the other graph in each pair, sketch the curve showing the relationship between the quantities labeled on the axes. Your graph should be consistent with the first graph in the pair.

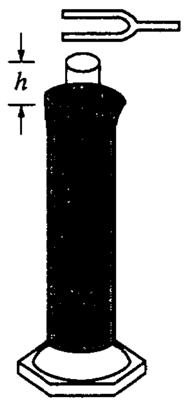




1995B6. A hollow tube of length L open at both ends as shown, is held in midair. A tuning fork with a frequency f_o vibrates at one end of the tube and causes the air in the tube to vibrate at its fundamental frequency. Express your answers in terms of L and f_o



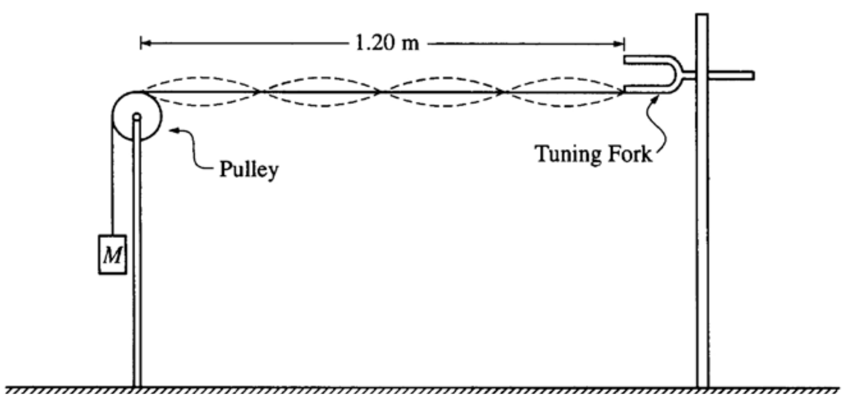
a. Determine the wavelength of the sound.
b. Determine the speed of sound in the air inside the tube.
c. Determine the next higher frequency at which this air column would resonate.



Note: Figure not drawn to scale.

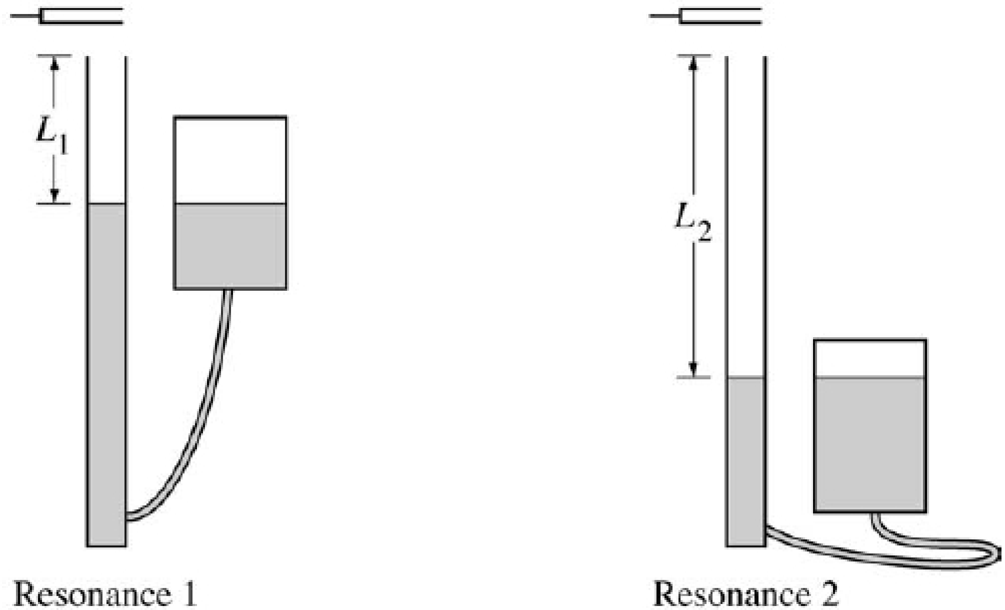
The tube is submerged in a large, graduated cylinder filled with water. The tube is slowly raised out of the water and the same tuning fork, vibrating with frequency f_o, is held a fixed distance from the top of the tube.

d. Determine the height h of the tube above the water when the air column resonates for the first time. Express your answer in terms of L.



1998B5. To demonstrate standing waves, one end of a string is attached to a tuning fork with frequency 120 Hz. The other end of the string passes over a pulley and is connected to a suspended mass M as shown in the figure above. The value of M is such that the standing wave pattern has four "loops." The length of the string from the tuning fork to the point where the string touches the top of the pulley is 1.20 m. The linear density of the string is 1.0×10^{-4} kg/m, and remains constant throughout the experiment.

a. Determine the wavelength of the standing wave.
b. Determine the speed of transverse waves along the string.
c. The speed of waves along the string increases with increasing tension in the string. Indicate whether the value of M should be increased or decreased in order to double the number of loops in the standing wave pattern. Justify your answer.
d. If a point on the string at an antinode moves a total vertical distance of 4 cm during one complete cycle, what is the amplitude of the standing wave?



Note: Figure not drawn to scale.

B2004B3. A vibrating tuning fork is held above a column of air, as shown in the diagrams above. The reservoir is raised and lowered to change the water level, and thus the length of the column of air. The shortest length of air column that produces a resonance is $L_1 = 0.25$ m, and the next resonance is heard when the air column is $L_2 = 0.80$ m long. The speed of sound in air at 20° C is 343 m/s and the speed of sound in water is 1490 m/s.

(a) Calculate the wavelength of the standing sound wave produced by this tuning fork.
(b) Calculate the frequency of the tuning fork that produces the standing wave, assuming the air is at 20° C.
(c) Calculate the wavelength of the sound waves produced by this tuning fork in the water, given that the frequency in the water is the same as the frequency in air.
(d) The water level is lowered again until a third resonance is heard. Calculate the length L_3 of the air column that produces this third resonance.
(e) The student performing this experiment determines that the temperature of the room is actually slightly higher than 20° C. Is the calculation of the frequency in part (b) too high, too low, or still correct?

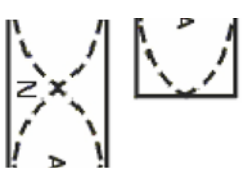
_____ Too high _____ Too low _____ Still correct Justify your answer.

AP Physics Multiple Choice Practice – Waves and Optics – ANSWERS

SECTION A – Waves and Sound

	Solution	Answer
1.	The given diagram is the 3rd harmonic at 60 Hz. That means the fundamental is 20Hz. The other possible standing waves should be multiples of 20	A
2.	Frequency and wavelength are inverses	A
3.	From diagram, wavelength = 0.5 m. Find the frequency with v = f λ	D
4.	After waves interfere they move along as if they never met	B
5.	For an open–open pipe the harmonic frequency is given by. $f_n = \frac{nv}{2L}$ with n=1	C
6.	When sound travels into less dense medium, its speed decreases (unlike light) … however, like all waves when traveling between two mediums, the frequency remains constant. Based on v = f λ, if the speed decreases and the frequency is constant then the λ must decrease also.	B
7.	Open–closed pipes only have odd multiples of harmonic so next f is 3x f_1	D
8.	For a given medium, speed is constant. Doubling the frequency halves the wavelength	A
9.	Determine each separate frequency using the speed of sound as 340 and v = f λ. Then subtract the two frequencies to get the beat frequency.	B
10.	Step the two pulses through each other a little bit at a time and use superposition to see how the amplitudes add. At first the amplitude jumps up rapidly, then the amplitude moves down as the rightmost negative pulse continues to propagate. At the very end of their passing the amplitude would be all the wave down and then once they pass the point will jump back up to equilibrium	C
11.	Wavelengths of each are (dist/cycle) … 4L, 4/3 L, 4/5 L, L, 2/3 L … Frequencies are f = v/ λ. v/4L, 3v/4L, 5v/4L, v/L, 3v/2L … Oy is 2x Cy	B,C
12.	f = cycles / seconds	D
13.	To use v = f λ, you also need the λ	B
14.	To produce pipe harmonics, the ends are always antinodes. The first (fundamental) harmonic is when there are two antinodes on the end and one node in-between. To move to each next harmonic, add another node in the middle and fill in the necessary antinodes. (ex, 2nd harmonic is ANANA … So the 4th harmonic would be ANANANANA and have four nodes. *Alternative solution … if you know what the harmonics look like you can draw them and manually count the nodes.*	C
15.	Since the medium stays the same the speed remains constant. Based on v = f λ, for constant speed, f and λ change as inverses.	A
16.	We should look at the harmonic shapes open–open vs open–closed.	D

L_1 L_2

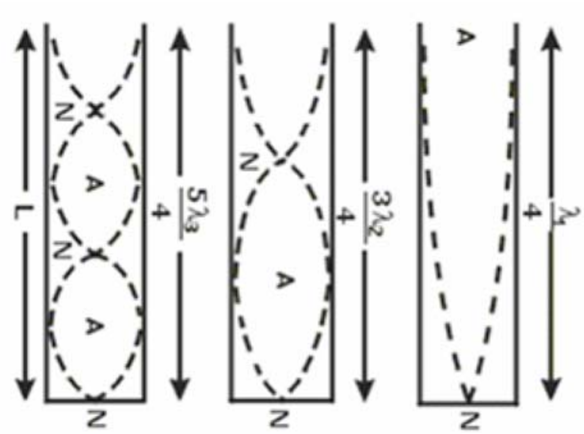


Comparing the fundamental harmonic of the open–open pipe to the closed–open pipe. The closed–open pipe should be half as long as the open–open pipe in order to fit the proper number of wavelengths of the same waveform to produce the given harmonic in each.

17. Two antinodes by definition will be ½ λ apart. So 20 cm = ½ λ, and the λ = 40 cm. Then using v = f λ we have 1200 = f (40) — D

18. This is similar to question 26, except now the length of the tube remains constant and the wave is changing within the tube to make each successive waveform (this would be like using different tuning forks each time for the same tube). The diagrams would look like this now: — C

5 3 1



Each λ is given by λ = dist / cycle
So
$\lambda_1 = 4L$
$\lambda_3 = 4/3\ L$
$\lambda_5 = 4/5\ L$

19. Doppler effect. The waves at right are compressed because the object is moving right. However, the waves are moving faster than the object since they are out in front of where the object is. — B

20. The time to make 1 cycle, is also the time it takes the wave to travel 1 λ. — A

21. Superpose the two waves on top of each other to get the answer. — B

22. Based on the diagram, the λ is clearly 2m. Plug into v = f λ. — D

23. The diagram shows the second harmonic in the string. Since harmonics are multiples, the first harmonic would be half of this. — B

24. A fact about the Doppler effect. Can also be seen from the Doppler equation (which is not required). — B, C

25. Use superposition and overlap the waves to see the resultant. — A

26. When hitting a fixed boundary, some of the wave is absorbed, some is reflected inverted. The reflected wave has less amplitude since some of the wave is absorbed, but since the string has not changed its properties the speed of the wave should remain unchanged. — C, D

27. Clearly at point C the waves are compressed so are more frequent. — C

28. Harmonics are multiples of the fundamental so the fundamental must be f/2. — B

29. Based on the Doppler effect, only speed matters. The faster a vehicle is moving, the closer together the sound waves get compressed and the higher the frequency. Take the case of a very fast vehicle traveling at the speed of sound; the compressions are all right on top of each other. So faster speed means closer compressions and higher frequencies. Choice I must be true because X is a higher frequency so must be going faster. Distance to the person affects the volume but not the pitch so choice II is wrong. III seems correct but its not. It doesn't matter whether you are speeding up or slowing down, it only matters who is going faster. For example, suppose truck X was going 5 mph and speeding up while truck Y was going 50 mph and slowing — A,D

down, this is an example of choice III but would not meet the requirement that X has a higher frequency because only actual speed matters, not what is happening to that speed.

30. By inspection. A

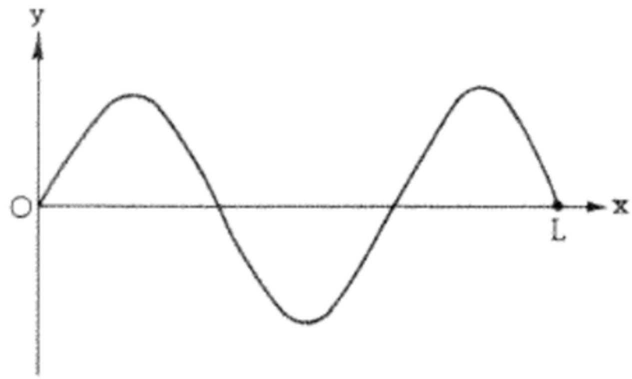
31. By inspection, the λ is 10 cm. f = 1 / T = 5, Then use v = f λ. C

32. A,C

Based on $v = \sqrt{\frac{F_t}{m/l}}$, the tension changes the speed. Then based on $f_n = \frac{nv}{2L}$, this resulting speed change will effect the frequency also. But since the frequency increases in direct proportion to the speed, and v = f λ, the λ should remain unchanged.
Note: equation of wave speed not required

1975B4.

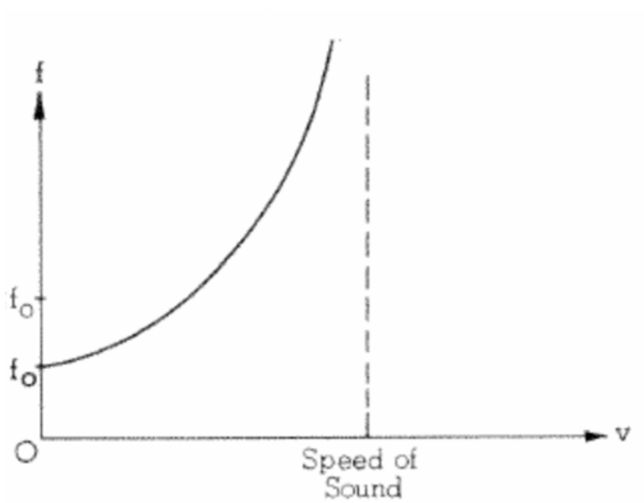
c) simple graph with 1.5x the frequency



d) Graphs are based on the Doppler equation. The graph given in the problem is for a moving observer.

Which is based on $f' = f\dfrac{(v_{snd} + v_{obs})}{v_{snd}}$. As the observer's velocity increases, the frequency increases linearly with it as is shown in the problem

The new graph is based on a source moving towards you. $f' = f\dfrac{v_{snd}}{(v_{snd} - v_{source})}$. As can be seed from this equation, as the source increases velocity, the frequency increases but when the source approaches the speed of sound, the frequency approaches ∞ and becomes undefined so has a limit to it unlike in the first graph.



1995B6.

a) The fundamental in a open–open pipe looks like this

and is ½ of a wavelength of the wave. Since this ½ wavelength fits in the length L, the total wavelength would have to be 2L.

b) Simply use $v = f\lambda \rightarrow v = 2Lf_o$

c) Harmonics are multiples of the fundamental, so the next frequency is $2f_o$

d) This is the same tuning fork so it is the same wavelength and waveform but the bottom is now closed so the wave looks like this.

The tube we had initially, fit ½ of a wavelength inside, and since its the same wavelength wave, again ½ of the wavelength of this wave would fit in length L and it would look like this.

This is impossible for a standing wave in an open–closed tube, and its also not the fundamental anyway so we have to change the length to make it look like the fundamental, Shown below. To do this, we make the length half of what it used to be.

h = L/2

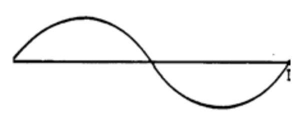
1998B5.

a) λ = dist / cycles = 1.2 m / 4 = 0.60 m

b) $v = f\lambda = (120)(0.60) = 72$ m/s

c) More 'loops' means a smaller wavelength. The frequency of the tuning fork is constant. Based on $v = f\lambda$, less speed would be required to make smaller wavelength. Since speed is based on tension, less M, makes less speed.

d) In one full cycle, a point on a wave covers 4 amplitudes … up, down, down, up. … So the amplitude is 1 cm.



B2004B3.

a) The shortest length makes the fundamental which looks like this  and is ¼ of the wavelength. This length is known to be 0.25m. So $L_1 = ¼ \lambda$ … $\lambda = 4L_1 = 1$m.

Note: This is a real experiment, and in the reality of the experiment it is known that the antinode of the wave actually forms slightly above the top of the air column (you would not know this unless you actually performed this experiment). For this reason, the above answer is technically not correct as the tube length is slightly less than 1/4 of the wavelength. The better way to answer this question is to use the two values they give you for each consecutive harmonic. You are given the length of the first frequency (fundamental), and the length of the second frequency (third harmonic). Based on the known shapes of these harmonics, the difference in lengths between these two harmonics is equal to ½ the wavelength of the wave. Applying this →

$\Delta L = ½ \lambda$ … $0.8–0.25 = ½ \lambda$ $\lambda_{actual} = 1.1$ m.

Unfortunately the AP exam scored this question assuming you knew about the correction; though you received 3 out of 4 points for using the solution initially presented. We teachers, the authors of this solution guide, feel this is a bit much to ask for.

b) Using $v = f \lambda$ with the actual λ … $(340) = f(1.1)$ … $f = 312$ Hz.

c) $v = f \lambda$ … $(1490) = (312)\lambda_{water}$ … $\lambda_{water} = 4.8$ m

d) Referring to the shapes of these harmonics is useful. The second length L_3 was the 3rd harmonic. The next harmonic (5th) will occur by adding another ½λ to the wave (based on how it looks you can see this). This will give a total length of $L_2 + ½ \lambda = (0.8) + ½ (1.1) = 1.35$ m

e) As temperature increases, the speed of sound in air increases, so the speed used in part (b) was too low. Since $f = v_{air} / \lambda$, that lower speed of sound yielded a frequency that was too low.