SECTION A – Waves and Sound

2. 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) 100 Hz   E) 180 Hz

4. A wave has a frequency of 50 Hz. The period of the wave is:
   A) 0.010 s   B) 0.20 s   C) 7 s   D) 20 s   E) 0.020 s

7. 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?
   A. 
   B. 
   C. 
   D. 
   E. 

10. An observer hears a sound with frequency 400 Hz. Its wavelength is approximately
   A) 0.85 m  C) 1.2 m  C) 2.75 m  D) 13.6 m  E) 44 m

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

13. 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) 60 Hz  B) 80 Hz  C) 120 Hz  D) 480 Hz  E) 720 Hz

Questions 15–16: A natural horn (trumpet with no valves) is similar to a pipe open at both ends. A musician plans to create a fundamental frequency of 256 Hz (middle C) using the horn.

15. If sound travels at 350 m/s, what must be the length of this horn?
   A) 0.34 m  B) 0.68 m  C) 0.78 m  D) 1.36 m  E) 1.46 m

16. A talented musician can produce a number of overtones on this natural horn. What would be the frequency of the fourth overtone produce when the musician is playing a middle C fundamental?
   A) 512 Hz  B) 768 Hz  C) 1024 Hz  D) 1280 Hz  E) 1536 Hz
17. 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) 66.5 Hz      D) 500 Hz      E) 11333 Hz

**Question 21–22:** 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.

![Graph of microphone voltage vs. time](image)

21. The frequency of the tuning fork is (approximately)
   A) 0.0039 s      B) 0.020 s      C) 2.55 Hz      D) 50 Hz      E) 256 Hz

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

23. A metal bar is vibrating with a frequency of 200 Hz. The resulting period of oscillation would be
   A) 200 s      B) 141 s      C) 0.007 s      D) 0.002 s      E) none of the above

24. A tube is open at both ends with the air oscillating in the 4th harmonic. How many displacement nodes are located within the tube?
   A) 2      B) 3      C) 4      D) 5      E) 6

25. Two separate strings of the same thickness are stretched so that they experience the same tension. String B is twice as dense as String A. String A, of length $L$, is vibrated at the fundamental frequency. How long is String B if it has the same fundamental frequency as String A?
   (a) $\frac{1}{2}L$      (b) $\frac{L}{\sqrt{2}}$      (c) $L$      (d) $\sqrt{2}L$      (e) $2L$

26. A resonance occurs with a tuning fork and an air column of size 39 cm. The next highest resonance occurs with an air column of 65 cm. What is the frequency of the tuning fork? Assume that the speed of sound is 343 m/s.
   (a) 329.8 Hz      (b) 527.7 Hz      (c) 659.6 Hz
27. A place of zero displacement on a standing wave is called
(a) an antinode.
(b) a node.
(c) the amplitude.
(d) the wavenumber.
(e) the harmonic.

28. 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) doubles and the wavelength is unchanged
(b) doubles and the wavelength doubled
(c) doubles while the wavelength is halved
(d) is unchanged while the wavelength is doubled
(e) is unchanged while the wavelength is halved.

29. 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) $\frac{1}{2}L_1$  E) $\frac{1}{4}L_1$

30. 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  (E) 20 Hz

31. 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, $\frac{1}{2}L$, $\frac{1}{4}L$  B) $\frac{1}{2}L$, $\frac{1}{4}L$, $\frac{1}{6}L$  C) 2L, L, $\frac{1}{2}L$  D) 4L, 2L, L  E) 4L, 4/3 L, 4/5 L

32. 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?

<table>
<thead>
<tr>
<th>Direction</th>
<th>Speed</th>
</tr>
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<tbody>
<tr>
<td>(A) To the right</td>
<td>Equal to v</td>
</tr>
<tr>
<td>(B) To the right</td>
<td>Less than v</td>
</tr>
<tr>
<td>(C) To the right</td>
<td>Greater than v</td>
</tr>
<tr>
<td>(D) To the left</td>
<td>Less than v</td>
</tr>
<tr>
<td>(E) To the left</td>
<td>Greater than v</td>
</tr>
</tbody>
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33. A cord of fixed length and uniform density, when held between two fixed points under tension T, vibrates with a fundamental frequency f. If the tension is doubled, the fundamental frequency is

(A) $2f$  (B) $\sqrt{2}f$  (C) $f$  (D) $\frac{f}{\sqrt{2}}$  (E) $\frac{f}{2}$
34. 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 frequency of the vibration  
(D) a distance directly proportional to the square root of the air density  
(E) a distance inversely proportional to the square root of the pressure

35. Two wave pulses, each of wavelength $\lambda$, 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 $\lambda$ apart, the shape of the rope is  
(A) $X \rightarrow Y$  
(B) $X \rightarrow Y$  
(C) $X \rightarrow Y$  
(D) $X \rightarrow Y$  
(E) $X \rightarrow Y$

36. A train whistle has a frequency of 100 hertz as heard by the engineer on the train. Assume that the velocity of sound in air is 330 meters per second. If the train is approaching a stationary listener on a windless day at a velocity of 30 meters per second, the whistle frequency that the listener hears is most nearly  
(A) 90 Hz  
(B) 110 Hz  
(C) 120 Hz  
(D) 240 Hz  
(E) 300 Hz

37. Two sinusoidal functions of time are combined to obtain the result shown in the figure above. Which of the following can best be explained by using this figure?  
(A) Beats  
(B) Doppler effect  
(C) Diffraction  
(D) Polarization  
(E) Simple harmonic motion

Questions 38-39

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.
38. 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      (E) 20 m/s

39. The fundamental frequency of vibration of the string is
   (A) 1 Hz      (B) 2.5 Hz      (C) 5 Hz      (D) 7.5 Hz      (E) 10 Hz

40. Sound in air can best be described as which of the following types of waves?
   (A) Longitudinal      (B) Transverse      (C) Torsional      (D) Electromagnetic      (E) Polarized

41. In the Doppler effect for sound waves, factors that affect the frequency that the observer hears include which of the following?
   I. The speed of the source
   II. The speed of the observer
   III. The loudness of the sound
   (A) I only       (B) III only      (C) I and II only      (D) II and III only      (E) I, II, and III

42. 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)  
(B)  
(C)  
(D)  
(E)  

43. 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 the wall. Properties of the reflected pulse include which of the following?

I. It has a greater speed than that of the incident pulse.
II. It has a greater amplitude than that of the incident pulse.
III. It is on the opposite side of the string from the incident pulse.
   (A)  I only           (B) III only          (C) I and II only           (D) II and III only           (E) I, II, and III

44. 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           (E) It will be the same at all four points.
45. 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) $2f$      (E) $3f$

46. 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
   I. It is traveling faster than truck Y
   II. It is close to the person than the truck Y
   III. It is speeding up, and truck Y is slowing down.
   (A) I only     (B) III only     (C) I and II only     (D) II and III only     (E) I, II and III

Questions 47–48:

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.

47. What is the amplitude of the wave?
   (A) 4 cm     (B) 5 cm     (C) 8 cm     (D) 10 cm     (E) 16 cm

48. What is the speed of the wave?
   (A) 4 cm/s     (B) 25 cm/s     (C) 50 cm/s     (D) 100 cm/s     (E) 200 cm/s

50. A tuning fork is used to create standing waves in a tube open at the top and partially filled with water. A resonance is heard when the water level is at a certain height. The next resonance is heard when the water level has been lowered by 0.5 m. If the speed of sound is equal to 340 m/s, the frequency of the tuning fork is
   (A) 170 Hz     (B) 226 Hz     (C) 340 Hz     (D) 680 Hz     (E) 2450 Hz