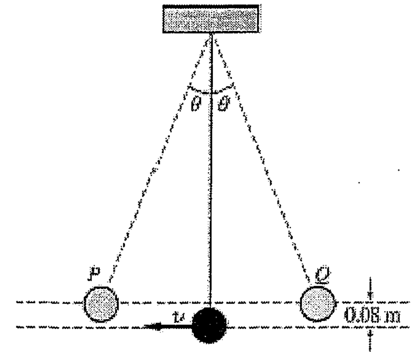
Name: KEY

Simple harmonic motion and waves problems

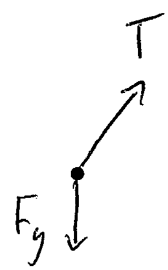
1. A simple pendulum system consists of a bob of mass 0.085 kg attached to a string length of 1.5 m. The pendulum is raised to point Q which is 0.08 m above its lowest position and released so that it oscillates with small amplitude θ between points P and Q as shown below.



Note: Figure not drawn to scale.

(a) On the figures below, draw free-body diagrams showing and labeling the forces acting on the bob in each of the situations described.

i. when it is at Point P



ii. When it is in motion at its lowest position

$T > F_g$
Because it is accelerating towards center of circle

(b) Determine the speed, v, of the bob at its lowest position.

$$K_{bot} + \underbrace{\cancel{GPE_{bot}}}_{0} = \underbrace{\cancel{K_P}}_{0} + GPE_P$$

$$\frac{1}{2}\cancel{m}v^2 = \cancel{m}gh$$

$$v = \sqrt{2gh} = \sqrt{2 \cdot 9.8 \cdot 0.08m} =$$

(c) Identify one modification that could be made to double the period of oscillation. Justify your answer.

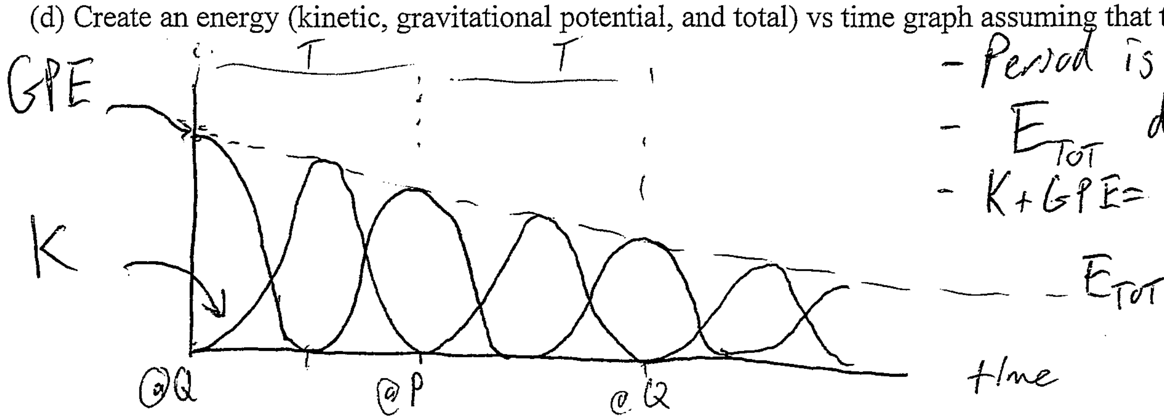
Length must increase by a factor of 4

B/c $T_p = 2\pi\sqrt{\frac{l}{g}}$

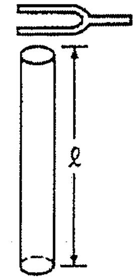
So, $L \rightarrow 6m$

(d) Create an energy (kinetic, gravitational potential, and total) vs time graph assuming that there **is air friction.**

- Period is constant
- E_{TOT} decays
- $K + GPE = E_{TOT}$



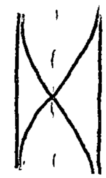
2. A hollow tube of length L open at both ends as shown, is held in midair. A tuning fork with a frequency
f_o vibrates at one end of the tube and causes the air in the tube to vibrate at its fundamental frequency. Express your answers in terms of L and f_o



a. Determine the wavelength of the sound. @ fundamental

$L = \lambda/2$

$\rightarrow \lambda = L \cdot 2$



$\lambda/2 = L$

b. Determine the speed of sound in the air inside the tube.

$V = f_o \lambda$

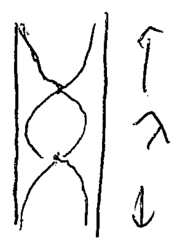
$V = f_o \cdot 2L = 2f_o L$

c. Determine the next higher frequency at which this air column would resonate.

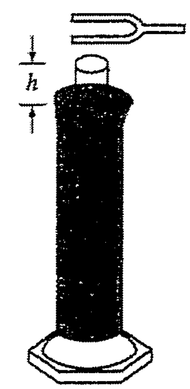
1 more node

$\lambda = L$

$V = f_1 \cdot L \qquad f_1 = \frac{V}{L} = \frac{2f_oL}{L} = \boxed{2f_o}$



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.



Note: Figure not drawn to scale.

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.

From before

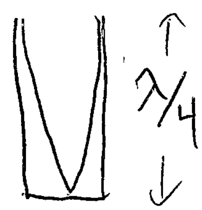
$V = f_o \lambda$

Same as before

$V = f_o \cdot 4h$

$2f_oL = f_o \cdot 4h$

$\boxed{\frac{L}{2} = h}$

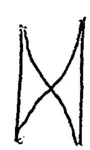


$\lambda/4 = h$

$h = \lambda/4$

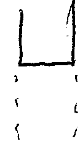
$\lambda = 4h$

Also: Since f is the same, know λ is same.

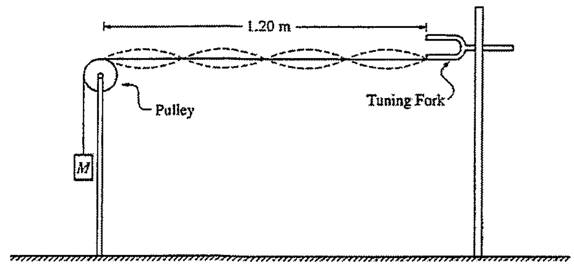


before

only want this now →



$h = L/2$



3. 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.

a. Determine the wavelength of the standing wave.

$1.2\,m = 2\lambda$

$\lambda = 0.6\,m$

b. Determine the speed of transverse waves along the string.

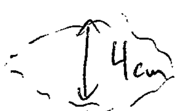
$v = f\lambda = 120\,Hz \cdot 0.6\,m$

$= 72\,m/s$

c. Indicate whether the value of M should be increased or decreased in order to double the number of loops in the standing wave pattern when using the same frequency. Justify your answer.

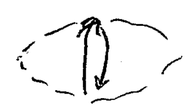
$v = f\lambda$ More loops → $\lambda \downarrow$ if f is constant, v must be reduced. To make v less, need less tension. ∴ Reduce M.

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?



A = 2 cm

Could be interpreted as



4 cm total → 2 cm top to bottom → A = 1 cm

Both OK.

e. If the string's length is cut in half at what frequency will a wave with four antinodes occur? How does this compare to the fundamental frequency?

$L = 0.6\,m$

4 antinodes.

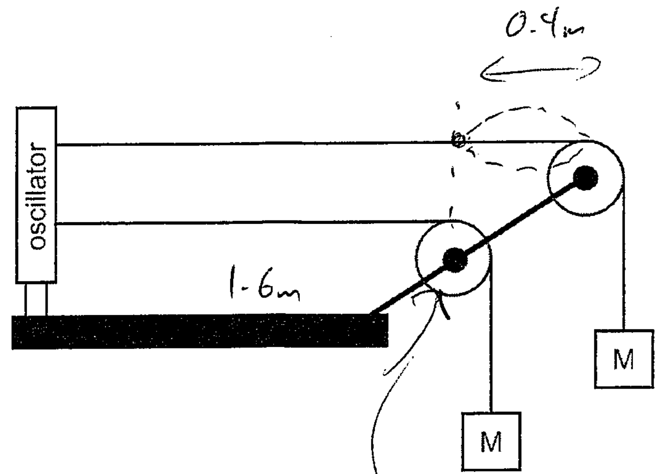
← 2λ →

$\lambda = 0.3\,m$

$f = \frac{v}{\lambda} = \frac{72\,m/s}{0.3\,m} = 240\,Hz$

Double! (Duy, λ was halved).

6. Two strings of the same material are connected to the same oscillator, pulled tightly over two light, frictionless pulleys and then connected to two 5 kg hanging masses as shown in the diagram. The oscillator can be set anywhere from 1 to 500 Hz. The only difference between the two strings is the length. The top string is 2 m long and the bottom string is 1.6 m long (both are measured from the oscillator to the pulley). Two students make predictions about when a frequency will be reached that will produce standing waves on both strings at the same time.



Student 1 predicts that the top string will have more loops than the bottom string because the speed of the wave on the top string is greater than the speed of the wave on the bottom string since the top string is longer.

Student 2 predicts that both strings will have the same number of loops because the speed of the waves on both strings is the same since they both have the same mass attached to them.

a. Which student (if any) made a correct prediction? (Ignore their reasoning for the moment.)

Student 1

b. Which student or students have correct reasoning? Explain your answer.

Student 2: Same wave speed, same frequency

If the frequency and the speed are the same for each string, what must be true about the wavelengths for each string? (this is not meant to be a hard question)

Same!

$v = f\lambda$

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

In order to have the bottom string resonate, the bottom string must have a node at 1.6 m. In order for the top string to resonate, there must be a node at 2.0 m. If they have the same wavelength, where can we conclude there is also a node for the top string? (this is not meant to be a hard question)

Must also have a node at 1.6m

c. Draw the simplest standing wave in the top string that satisfies what we just said. How many loops will be on each string the first time a standing wave is produced on both strings at the same time?

Each loop must be 0.4 m (distance between nodes)

Top: 2.0m / 0.4m = 5 loops

bottom: 1.6m / 0.4m = 4 loops

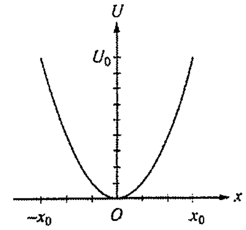
d. Calculate the lowest frequency that can be set so that the oscillator will produce a standing wave for both strings at the same time.

Given: $v = 160\,m/s$

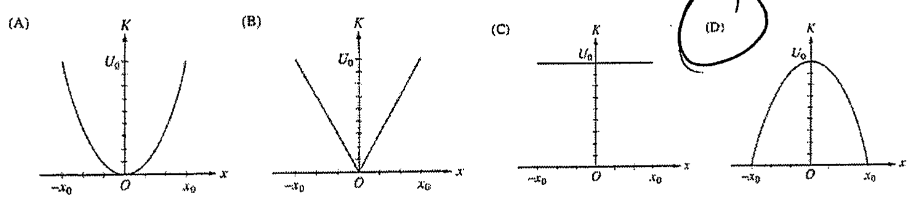
$\lambda/2 = 0.4\,m \rightarrow \lambda = 0.8\,m$

$v = f \cdot \lambda \quad f = \frac{v}{\lambda} = \frac{160\,m/s}{0.8\,m} = 200\,Hz$

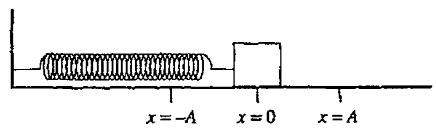
7. The graph shown represents the potential energy U as a function of displacement x for an object on the end of a spring moving back and forth with amplitude x_0.



Which of the following graphs represents the kinetic energy K of the object a function of displacement x ?



8. A block on a horizontal frictionless plane is attached to a spring, as shown. The block oscillates along the x-axis with amplitude A. Which of the following statements about energy is correct?



(A) The potential energy of the spring is at a minimum at x = 0.
(B) The potential energy of the spring is at a minimum at x = A.
(C) The kinetic energy of the block is at a minimum at x =0.
(D) The kinetic energy of the block is at a maximum at x = A

9. A mass m is attached to a spring with a spring constant k. If the mass is set into motion by a displacement d from its equilibrium position, what would be the speed, v, of the mass when it returns to equilibrium position?

(A) $v=\sqrt{\frac{kd}{m}}$ (B) $v=d\sqrt{\frac{k}{m}}$ (C) $v=\frac{kd}{mg}$ (D) $v^2=\frac{mgd}{k}$

$\frac{1}{2}mv^2=\frac{1}{2}kx^2$

$v^2=\frac{kd^2}{m} \Rightarrow v=d\sqrt{\frac{k}{m}}$

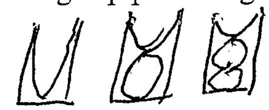
10. **Multiple Correct:** A standing wave pattern is created on a guitar string as a person tunes the guitar by changing the tension in the string. Which of the following properties of the waves on the string will change as a result of adjusting only the tension in the string? Select two answers.
A) the speed of the traveling wave that creates the pattern
B) the wavelength of the standing wave ← Still first mode, L didn't change.
C) the frequency of the standing wave
D) the amplitude of the standing wave

11. **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.

12. 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*

$\lambda/2 = 20$ cm
$\lambda = 40$ cm
$f = v/\lambda$

13. What would be the wavelength of the fundamental and first two modes 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



14. Resonance occurs in a soft drink bottle as air is blown across its top. What property of the resonant sound wave in the bottle remains the same as the level of fluid in the bottle decreases?

I. The speed of the wave
II. The wavelength of the wave
III. The frequency of the wave

(A) I only
(B) II only
(C) III only
(D) I and II only
(E) I, II, and III

15. A stationary source emits sound waves of frequency f and wavelength λ that travel through the air with speed v. If the frequency of the source is changed to $2f$, what will be the wavelength and speed of the new wave?

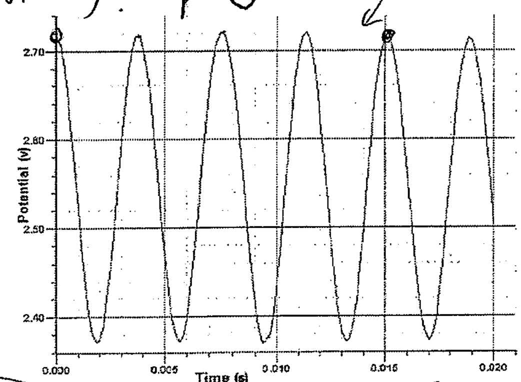
	Wavelength	Speed
(A)	2λ	v
(B)	λ	$2v$
(C)	λ	$v/2$
(D)	$\lambda/2$	$2v$
(E)	$\lambda/2$	v

16. **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 ← This means where the sine wave is starting.

vs

about 4 periods

Questions 17-18: The graph to the right was produced by a microphone in front of a tuning fork. It shows the voltage produced from the microphone as a function of time.

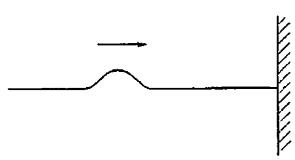


17. The frequency of the tuning fork is (approximately)
A) 0.004 s B) 0.020 s C) 50Hz D) 250 Hz

18. 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

T = 0.015/4
T = 266Hz

19. **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.

On collisions some energy is lost