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1. [5 pts] The position of a particle undergoing simple harmonic motion is described by the equation $x(t) = A\sin\left(Bt + \frac{\pi}{3}\right)$, where $A = 7.50$ m and $B = 4.00\ \mathrm{s}^{-1}$. What is the velocity of the particle at $t = 0$?

A) 3.75 m/s

B) 6.50 m/s

C) 15.0 m/s

D) 26.0 m/s

E) 30.0 m/s

2. [5 pts] An ideal spring is suspended from the ceiling. When no mass is attached, its length is 10.0 cm. A 5.00 kg mass is then hung from the spring. When the 5.00 kg mass is at rest, the spring has a length of 12.0 cm. The mass is then pulled down slightly and released, setting it into vertical oscillation. What is the period of this oscillation?

A) 0.284 s

B) 0.631 s

C) 0.700 s

D) 1.26 s

E) 2.00 s

3. [5 pts] The pendulum outside the physics classroom has a period of 7.90 s. Now it is moved to the surface of Jupiter where the gravity is 2.50 times stronger than the gravity on the surface of earth. What is the new period?

A) 19.8 s

B) 12.5 s

C) 7.90 s

D) 5.00 s

E) 3.20 s

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4. [5 pts] A block attached to an ideal spring oscillates horizontally on a frictionless surface. Consider a system consisting of the spring and block. If the amplitude of oscillation is doubled, what happens to the total mechanical energy of the system?

A) It becomes half as large.

B) It is unchanged.

C) It becomes four times larger.

D) It becomes two times larger.

E) More information is required to answer.

5. [5 pts] A traveling pulse is described by the time-dependent wave function $y(x,\ t) = \frac{A}{1+(Bx - Ct)^2}$ where $A = 5.0$ m , $B = 0.20\ \text{m}^{-1}$; $C = 2.5\ \text{s}^{-1}$. What is the wave speed of this pulse?

A) 0.10 m/s

B) 0.50 m/s

C) 2.5 m/s

D) 5.0 m/s

E) 12.5 m/s

6. [5 pts] A small speaker emits sound waves equally in all directions. The sound intensity level at 2.00 m from the speaker is 80.0 dB. At what distance from the speaker would the sound intensity level drop to 60.0 dB?

A) 4.00 m

B) 10.0 m

C) 20.0 m

D) 40.0 m

E) 60.0 m

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7. [5 pts] The electric bells at your school buzz with a frequency of 450 Hz. If you are late for class and riding your bike down a hill toward the school at a constant speed of 4.47 m/s, what is the frequency of the sound you hear? Assume that the speed of sound is 343 m/s.

   A) 438 Hz
   B) 444 Hz
   C) 450 Hz
   D) 456 Hz
   E) 462 Hz

8. [5 pts] A standing wave with three antinodes is established in a closed-closed pipe when the air inside is vibrated at a frequency of 300 Hz. What is the smallest frequency at which the air can be vibrated to produce any standing wave in the pipe?

   A) 50 Hz
   B) 100 Hz
   C) 150 Hz
   D) 200 Hz
   E) 300 Hz

9. [5 pts] A thin film of soap ($n = 1.55$) with a thickness, t, floats on water ($n = 1.33$). Which condition leads to constructive interference for reflected light of wavelength λ in the film?

   A) $2t = \frac{m\lambda}{n_{film}}$ for $m = 0, 1, 2..$
   B) $2t = \frac{\left(m+\frac{1}{2}\right)\lambda}{n_{film}}$ for $m = 0, 1, 2..$
   C) The path difference must be zero.
   D) Constructive interference is impossible in this situation.

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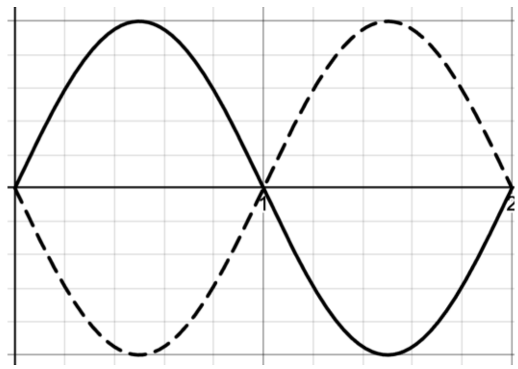
Lab Multiple Choice Questions

10. [5 pts] In Lab A1, two groups of students, group 1 and group 2 have adjusted the function generator to a frequency f_0 to form the standing wave at right. The string has a length L_0, and the mass of the hanger is m_0. Group 1 has decided to investigate how the standing wave frequency varies with length and group 2 is investigating how the standing wave frequency varies with mass.



Group 1 changes the length of the string to $2L_0$ and group 2 changes the mass of the hanger to $m_0/4$. How should the groups change the function generator to find the same standing wave pattern?

A) Group 1 should decrease the frequency to $f_0/2$, and group 2 should increase the frequency to $\sqrt{2}f_0$.

B) Group 1 should increase the frequency to $4f_0$, and group 2 should decrease the frequency to $f_0/\sqrt{2}$.

C) Group 1 should increase the frequency to $2f_0$, and group 2 should decrease the frequency to $f_0/\sqrt{2}$.

D) Group 1 should decrease the frequency to $f_0/2$, and group 2 should decrease the frequency to $f_0/2$.

E) Other

The frequency of a standing wave on a string is given as follows:

$$f_m = m\frac{v}{\lambda} = m\frac{\sqrt{\frac{T}{\mu}}}{2l}$$

This equation can be rearranged such that the mode (m) is the subject of the equation.

$$m = \frac{f_m 2l}{\sqrt{\frac{T}{\mu}}}$$

And the tension in the string is equal to magnitude of the gravitational force of the hanging mass.

$$T = m_{hanger}g$$

The mode number is thus proportional to both the driving frequency and the length and inversely proportional to $\sqrt{T}$. Since group 1 doubles the length of the string, the driving frequency should be halved to keep the same mode number. And since group 2 decreases the tension by one-quarter and the square root of a quarter is one-half, group 2 should also decrease the frequency to $f_0/2$.

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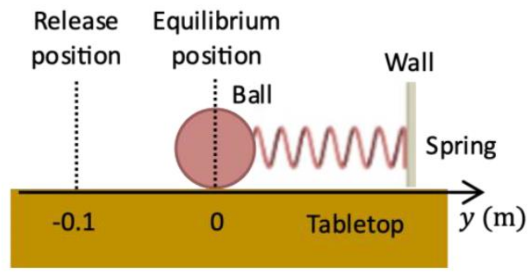
11. [5 pts] As part of Lab 2 homework and Lab A2, you examined the context at right. For this question, the ball has a mass 0.2500 kg and is resting on a frictionless tabletop. The ball is connected to one end of a spring with spring constant 4.000 N/m. The other end of the spring is attached to a wall that does not move. The position of the ball measured from equilibrium position is *y*. The ball is pulled 0.1000 m in the negative *y*-direction from the equilibrium position, and at time *t* = 0 s it is released from rest.



Using the same assumptions as those stated in the Phys 123 lab homework, what is the position of the ball at *t* = 0.01 s?

A) -0.09980 m

B) -0.09984 m

C) -0.09987 m

D) -0.09990 m

E) -0.09992 m

1. *We first calculate the net force on the ball when it is displaced 0.1 m from equilibrium.*

$$F_{net} = F_{by\ spring} = k\Delta l = (4\ \mathrm{N/m})(0.1\ \mathrm{m}) = 0.4\ \mathrm{N}$$

2. *We then use this force and Newton's second law to calculate the acceleration:*

$$a = \frac{F_{net}}{m} = \frac{0.4\ \mathrm{N}}{0.25\ \mathrm{kg}} = 1.6\ \mathrm{m/s^2}$$

3. *We then assume this acceleration is constant and find the speed at the end of the small time interval (0.01 s).*

$$v_f = v_i + at = (0\ \mathrm{m/s}) + (1.6\ \mathrm{m/s^2})(0.01\ \mathrm{s}) = 0.016\ \mathrm{m/s}$$

4. *We then consider the ball having this speed for the small-time interval and find its position.*

$$x_f = x_i + vt = -0.1\ \mathrm{m} + (0.016\ \mathrm{m/s})(0.01\ \mathrm{s}) = -0.09984\ \mathrm{m}$$

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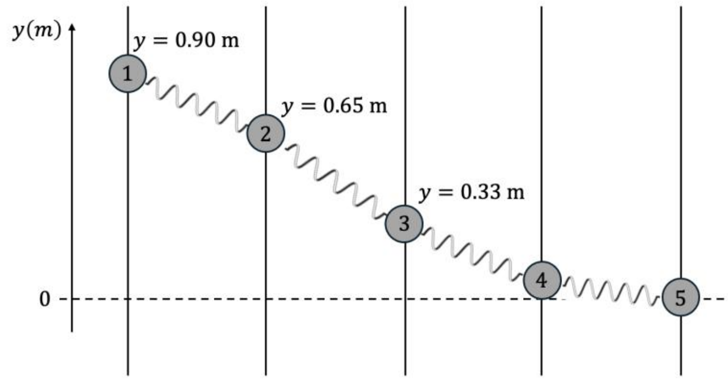
12. [5 pts] For the simulation of the five balls in Lab A2, balls 2, 3, and 4 are free to move and the net force on each of these balls is due to the springs to the left and right. For this question, **use the following assumption which is the same as that in the lab**:



> Assume that the force from the left spring on ball 2 only depends on the difference of y positions of balls 1 and 2. Likewise, assume the force from the right spring on ball 2 only depends on the difference in the y positions of balls 2 and 3.

As noted in Q11, the balls have a mass of 0.250 kg, and the spring constant of each spring is 4.00 N/m. Ball 1 is displaced at $t = 0$ s, and the displacement of balls 1, 2, 3 at $t = 1.0$ s is shown above. What is the magnitude of the acceleration of ball 2 at this instant?

A) $1.1\ \mathrm{m/s^2}$

B) $0.78\ \mathrm{m/s^2}$

C) $5.1\ \mathrm{m/s^2}$

D) $2.3\ \mathrm{m/s^2}$

E) $11\ \mathrm{m/s^2}$

1. *We first calculate the net force on ball when it is displaced 0.65 m from its equilibrium position. Note that the left spring is pulling upward and the right spring is pulling downward. The different force directions must be taken into account.*

$$\vec{F}_{net} = \vec{F}_{by\ left\ spring} + \vec{F}_{by\ right\ spring}$$

$$F_{net} = k(y_1 - y_2) - k(y_2 - y_3)$$

$$F_{net} = k[(y_1 - y_2) - (y_2 - y_3)] = (4\ \mathrm{N/m})[(0.9\ \mathrm{m} - 0.65\ \mathrm{m}) - (0.65\ \mathrm{m} - 0.33\ \mathrm{m})]$$

$$F_{net} = -0.28\ \mathrm{N}$$

2. *We then use this force and Newton's second law to calculate the magnitude of the acceleration:*

$$|a| = \frac{|F_{net}|}{m} = \frac{|-0.28\ \mathrm{N}|}{0.25\ \mathrm{kg}} = 1.1\ \mathrm{m/s^2}$$

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Lecture Free Response

Consider the following scenario for the next three questions.

You attach one end of a thin string firmly to a pole at $x = 0.0$ m and hold the other end at $x = 3.0$ m so that the string is along the x-direction. At $t = 0.0$ s, you start moving the end of the string you are holding vertically. The graph below shows the history graph of a point P, which is at $x = 1.2$ m.

13. [5 pts] What is the wave speed of this string? Show your work.

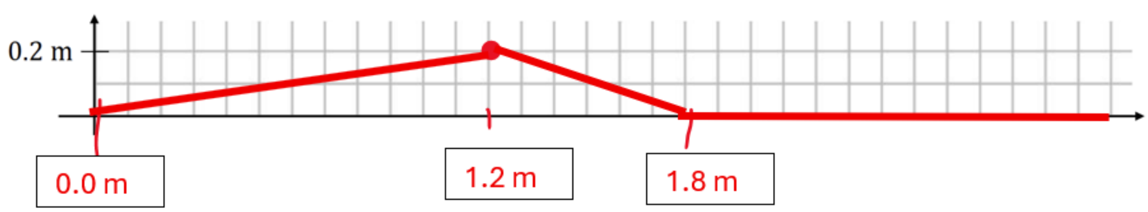
Consider the following kinematic equation:

$$\Delta x = v\Delta t \Longrightarrow v = \frac{\Delta x}{\Delta t}$$

We use the position of point P, x = 1.2 m. The pulse starts at x = 3.0 m and traveling towards – x direction. From the history graph the string element at point P starts to move at 0.6 s. Therefore:

$$v = \frac{\Delta x}{\Delta t} = \frac{3.0 - 1.2\, m}{0.6\, s} = 3\, ms^{-1}$$

14. [5 pts] On the graph below, draw the snapshot graph at $t = 1.0$ s. Be sure to include the entire pulse and label the tick marks on the horizontal axis such that we can determine the scale.



Since the pulse is moving at 3.0 m/s, the leading edge should be at 0.0 m. There is 0.6 s between the leading and trailing edge, so the pulse should be 1.8 m wide, meaning the trailing edge is at 1.8 m. Noting the assymetry from the history graph, the peak should be at 1.2 m.

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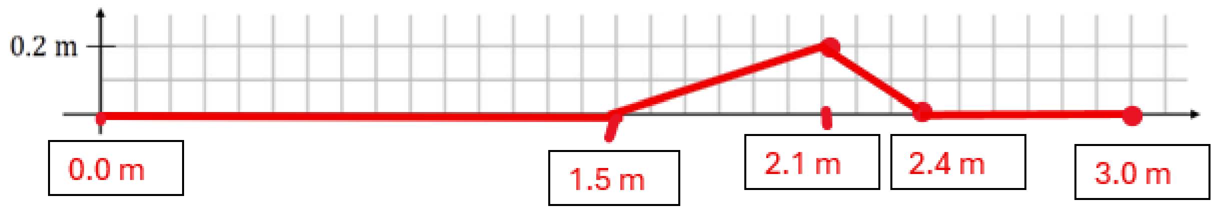
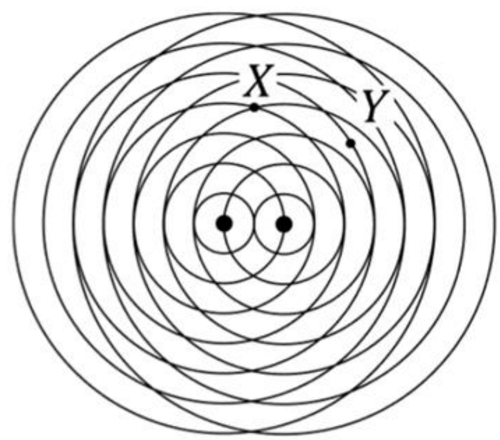
15. [5 pts] Suppose that the tension in the string is decreased by a factor of four ($T_{new} = T_{original}/4$). The student generates the pulse in exactly the same way. On the graph below, draw the snapshot graph of point P at t = 1.0 s. Be sure to to include the entire pulse and label the tick marks on the horizontal axis such that we can determine the scale.

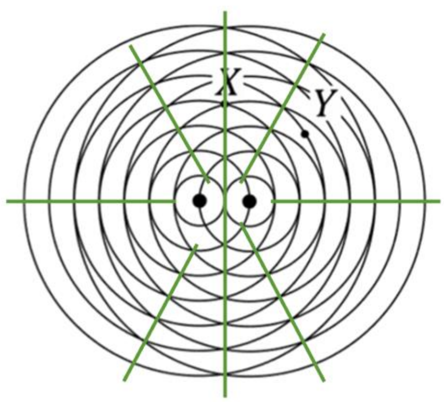


Reducing the tension to one-quarter of the original value reduces the speed by a factor of two. This means that the leading edge will travel half the distance as that in Q14 and the pulse will be half the width as that in Q14.

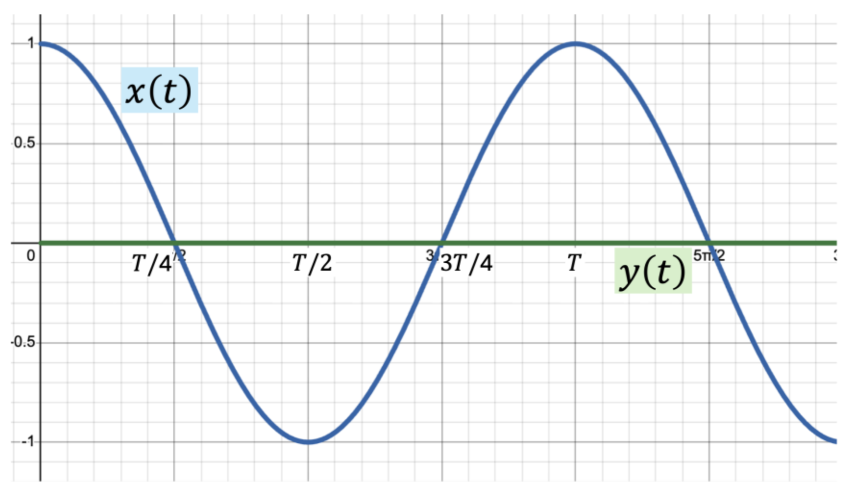
Consider the following scenario for the next two questions.
Surface waves are generated from two coherent sources separated by a small distance. The figure shows the crests of the waves at $t = 0$.



16. [5 pts] Draw all the antinodal lines on the figure.



17. [5 pts] On the axes below sketch the displacement curve at point X and Y as a function of time starting at $t = 0$. Indicate which curve is which. Indicate the time corresponding to the period, T, on your graph.



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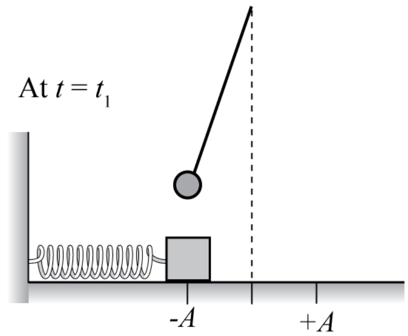
Tutorial Free Response Questions

18. [5 pts] A pendulum is hung directly above a block that is connected to an ideal spring. The surface is frictionless, and the block and pendulum bob have the same mass, *m*. At $t = t_1$, the pendulum bob and block are both instantaneously at rest.



Consider the following systems:

- System 1: Pendulum and Earth
- System 2: Block and Spring

For which of these systems, if any, can the total energy be determined without knowing the value of *m*? Explain.

For the block-spring system, the total energy can be written as follows:

$$E_{total} = U_{max} = \frac{1}{2}kA^2 = K_{max} = \frac{1}{2}mv_{max}^2$$

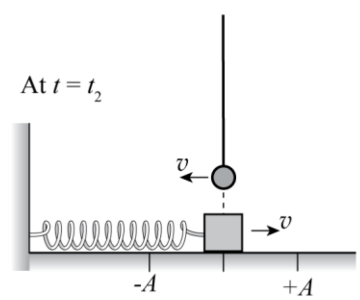
Since the total energy can be determined from the spring constant and the amplitude of the oscillation, it is not necessary to know the value of the mass of the block.

The total energy of the pendulum-Earth system can be written as:

$$E_{total} = mgy_i$$

Where y_i *defines the initial height of the bob above some the reference point* $y = 0$. *From this equation, it can be concluded that the total energy of the pendulum-Earth system is dependent on the bob's mass.*

19. [5 pts] A short time later, at $t = t_2$, the block has reached its equilibrium position for the first time, and the pendulum bob has reached its equilibrium position for the second time.



When the pendulum reaches its rightmost position for the second time, what is the position of the block and in what direction is it moving? Explain.

At $t = t_2$, *the pendulum bob has completed ¾ of its cycle and the block has completed ¼ of its cycle. We can thus write the following relationship:*

$$\frac{3}{4}T_{pendulum} = \frac{1}{4}T_{block}$$

$$3T_{pendulum} = T_{block}$$

When the pendulum reaches the rightmost position for the second time, it will have completed 1.5 cycles, which means that the block will have completed half a cycle. This means that block is located at x = +A and is instantaneously at rest.

20. [5 pts] A student wants to alter the experiment such that the bob is always directly over the block as they oscillate. They determine that increasing the length of the pendulum by a factor x produces the desired result. Which of the choices at right (A to D) would alternatively provide the same result (assuming the pendulum remains at its original length)? Explain.

A. Increase the spring constant by the same factor x.
B. ~~Increase the mass of the block by the same factor~~ x.
C. ~~Increase the mass of the bob by the same factor x.~~
D. More than one of these.

For the bob to remain directly over the block, the bob and the block must have the same period. The period of the bob and the period of the block are given by the following equations respectively:

$$T_{bob} = 2\pi\sqrt{\frac{l}{g}}$$

$$T_{block} = 2\pi\sqrt{\frac{m}{k}}$$

The period of the pendulum is not a function of the mass of the bob, so C is incorrect.

Originally, the pendulum's period was one-third of the period of the block. To equate the periods, the period of the pendulum must be increased by a factor of three, which means that the student must have increased the length of the pendulum by a factor of nine ($T_{bob} \propto \sqrt{l}, l_{new} = 9l_{orig}$).

This makes factor x equal to 9.

If the pendulum remains at its original length, the period of the block must be decreased by a factor of 3 to match the pendulum's period. This is achieved by increasing the spring constant by a factor of nine ($T_{block} \propto \sqrt{\frac{1}{k}}, \sqrt{\frac{1}{9}} = \frac{1}{3}$. This makes choice A correct.