Q1–Q15: Lecture multiple choice — Indicate your answer on the bubble sheet.

1. [4 pts] An ideal spring-block system is pulled back 3.5 cm from its equilibrium position and then released from rest. It takes 0.09 s for the system to first reach its equilibrium position. What is the frequency of the system?

   A. 2.8 Hz

   B. 3.7 Hz

   C. 5.6 Hz

   D. 8.8 Hz

   E. 11 Hz

2. [4 pts] A certain simple harmonic oscillator has maximum velocity +5 m/s and maximum acceleration +15 m/s^2. How much time will it take the oscillator to undergo 4 complete oscillations?

   A. 3.5 s

   B. 5.7 s

   C. 8.4 s

   D. 12 s

   E. 14 s

3. [4 pts] The frequency of an ideal spring-block system is measured to be 5.8 Hz. You then **double the mass** of the block and pull back the block twice as far before so that its **amplitude is also doubled.** What is the new frequency of the system?

   A. 2.9 Hz

   B. 3.3 Hz

   C. 3.8 Hz

   D. 4.1 Hz

   E. 5.8 Hz

4. [4 pts] The angle θ in radians of a certain simple pendulum is described by the equation $\theta(t) = (0.1\ \text{rad})\sin\left[\left(5.0\frac{\text{rad}}{\text{s}}\right)t\right]$ where *t* represents time. What is the length of the pendulum?

   A. 0.21 m

   B. 0.25 m

   C. 0.33 m

   D. 0.39 m

   E. 0.45 m

5. [4 pts] Which of the following best describes the properties of visible light and of sound waves in a flute?

A	Visible light: Electromagnetic, longitudinal Sound in a flute: Mechanical, longitudinal
B	Visible light: Electromagnetic, longitudinal Sound in a flute: Mechanical, transverse
C	Visible light: Electromagnetic, transverse Sound in a flute: Mechanical, longitudinal
D	Visible light: Electromagnetic, transverse Sound in a flute: Mechanical, transverse
E	None of these are correct

6. [4 pts] You have a spring of mass 0.04 kg. You fix one end to a wall and exert a horizontal force of magnitude 2.3 N to the other end, which causes the spring to stretch to a length of 3.6 m.

   If you quickly shake the end of the spring you are holding, how much time will it take for the resulting pulse to reach the wall?

   A. 0.07 s

   B. 0.13 s

   C. 0.18 s

   D. 0.22 s

   E. 0.25 s

7. [4 pts] Suppose that the molar mass of a certain diatomic molecule ($\gamma = 1.4$) is 34.0 g/mol = 0.0340 kg/mol. You measure the speed of sound to be 240 m/s in a sample of gas composed entirely of this diatomic molecule at some unknown temperature T_0.

   Later, you replace the diatomic gas with a different diatomic gas at the same unknown temperature T_0. The speed of sound is now measured to be 310 m/s. What is the molar mass of a **single atom** (not a single molecule) of the element that comprises the diatomic molecule?

   A. 56.7 g/mol
   B. 28.4 g/mol
   C. 20.4 g/mol
   D. 14.2 g/mol
   E. 10.2 g/mol

8. [4 pts] You and a classmate are holding a very long spring between yourselves. Your friend is shaking the end of the spring and creating sinusoidal traveling waves that **travel at speed v_0** and have **wavelength λ_0.**

   Suppose now that your classmate shakes the spring at a different rate, but no other changes are made to the spring. As a result of this change, the wavelength of the waves is now observed to be $3\lambda_0$. What is the new wave speed of the traveling waves?

   A. $9v_0$
   B. $3v_0$
   C. v_0
   D. $v_0/3$
   E. $v_0/9$

9. [4 pts] A traveling transverse wave is described by the equation $y(x,t) = (0.020 \text{ m}) \sin(5.5x + 3.3t)$ where x and t are measured in meters and seconds, respectively. What are the **speed** and **direction of propagation** of the wave?

   A. 0.6 m/s in the $+x$ direction

   B. 0.6 m/s in the $-x$ direction

   C. 1.7 m/s in the $+x$ direction

   D. 1.7 m/s in the $-x$ direction

   E. None of these are correct.

10. [4 pts] Ultrasonic imaging involves sending ultrasonic waves into the body. The waves leave an emitter at the surface of the skin, reflect from an object within the body, and finally are received by the same instrument that emitted the waves.

    An ultrasound technician will study an organ that is 0.0500 m below the surface of the skin. The speed of sound in the body is 1540 m/s. If the technician only wants **one pulse** present in the body at a time, how many pulses per second can the technician send into the body?

    A. 15,400

    B. 18,000

    C. 30,800

    D. 36,000

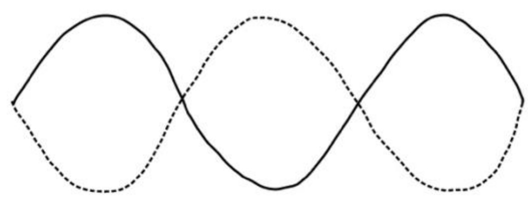
    E. 61,600

11. [4 pts] A speaker emits sound with a power rating of 5.0 W. You have a decibel meter and measure the sound intensity level to be 80 dB.

    How far away from the speaker are you standing? As usual, assume the speaker emits sound uniformly in all directions. Recall that the intensity corresponding to the threshold of human hearing is 10^{-12} W/m^2.

    A. 42 m
    B. 63 m
    C. 72 m
    D. 81 m
    E. 95 m

12. [4 pts] The standing wave at right is established in a medium that has length 0.40 m and wave speed 200 m/s. What is the **fundamental frequency** of the medium?



    A. 250 Hz
    B. 500 Hz
    C. 600 Hz
    D. 750 Hz
    E. 1000 Hz

13. [4 pts] Suppose that when a guitar string is plucked, we hear a frequency of 440.0 Hz, which is known as an "A4" note. When the string is pressed just behind the 7^{th} fret of the guitar and plucked, we hear a frequency close to 659.3 Hz, which is an "E5" note. (Recall we discussed frets in class.)

Which of the following **best** explains why we hear a different note when the string is pressed behind the 7^{th} fret?

A. The tension in the guitar string changes by a large amount because the vibrating portion of the string is shorter.

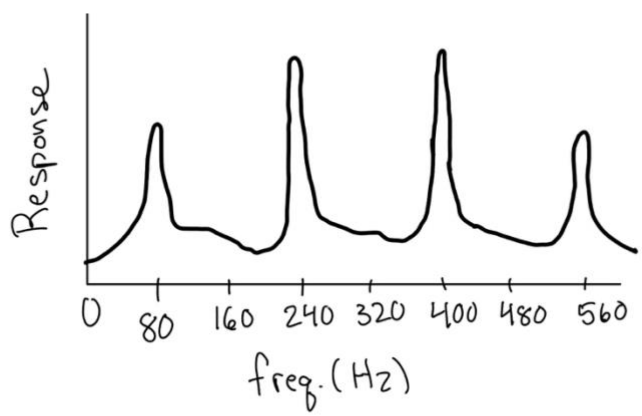
B. The linear mass density in the guitar string changes by a large amount because the vibrating portion of the string is shorter.

C. The fixed-fixed string changes to a fixed-free string because the portion of the string "behind" the fret is now free to oscillate how it wishes.

D. There are now a greater number of antinodes on the vibrating portion of the string, which is now shorter.

E. The fundamental frequency of the string is now different because the vibrating portion of the string is shorter.

14. [4 pts] The diagram at right shows the response curve for a certain instrument that uses standing waves of air (v_{air} = 343 m/s) to produce sound. What is the length of the instrument represented in the diagram?



A. 0.408 m

B. 1.07 m

C. 2.14 m

D. 3.21 m

E. 4.29 m

15. [4 pts] Two different speakers are playing pure sine wave sounds of slightly different frequencies.
    - When **both speakers** are playing, you hear a beat frequency of 4 Hz.
    - When only the **left speaker** is playing, you hear a frequency of 225 Hz.

    What frequency will you hear if only the right speaker is playing?

    A. 4 Hz

    B. 221 Hz

    C. 229 Hz

    D. Could be either B or C

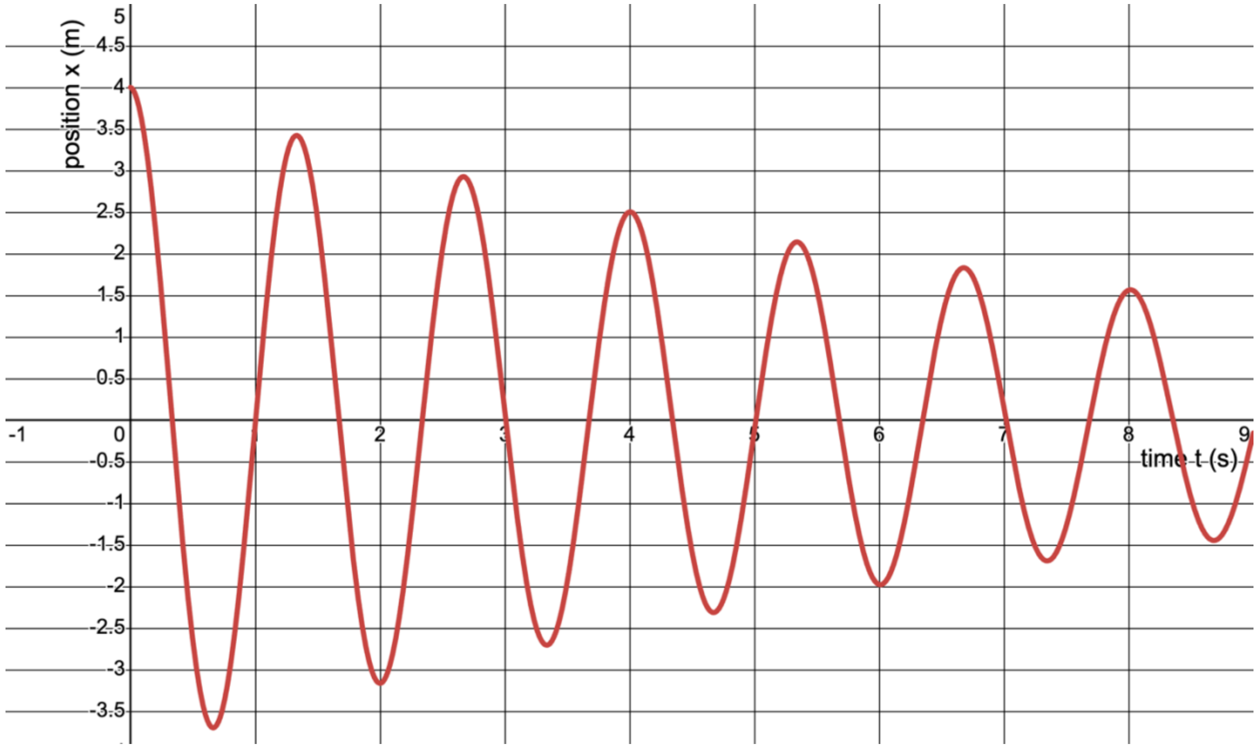
    E. None of the above.

Q16–Q20: Lecture free response — Unless otherwise noted, explain your reasoning or show your work.

16. [4 pts] A certain simple harmonic oscillator has an equilibrium position at $x = 0$. At time $t = 0$, the oscillator is at the equilibrium position and moving in the negative x-direction. It takes 0.25 s for the oscillator to first return to the equilibrium position. The maximum displacement of the oscillator from equilibrium is 0.40 m.

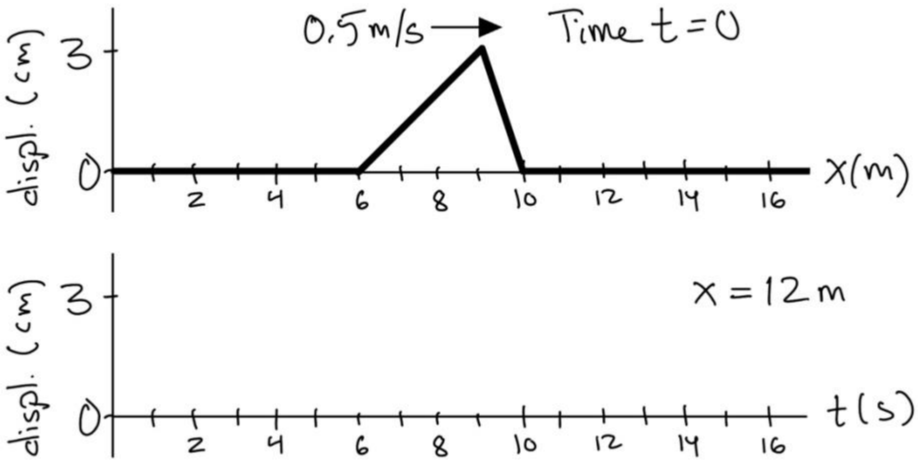
    Write down a mathematical function for the velocity $v_x(t)$ of the oscillator. Your function should give the velocity in units of meters/second when time is expressed in seconds. Explain and/or show your work.

17. [4 pts] The graph below represents position versus time for a damped harmonic oscillator.



At what time will the maximum transverse displacement of the motion be reduced to 0.50 m? Show your work.

18. [4 pts] The top diagram represents a snapshot graph of a transverse pulse as it travels in the $+x$-direction at a speed of 0.5 m/s. The snapshot represents the displacement of the spring at time $t = 0$ s.



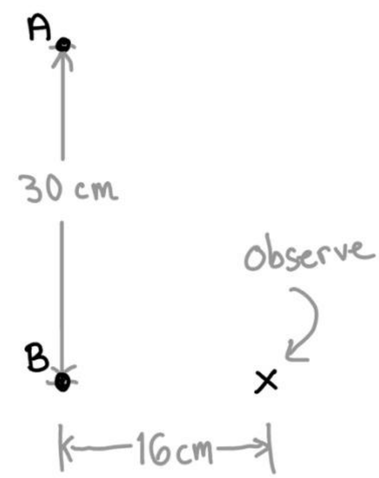
On the blank axes above, sketch the **history graph** for the **position x = 12 m.** No explanation is necessary

19. [4 pts] A fixed-fixed standing wave on a string has 3 antinodes and oscillates at a frequency of 360 Hz. Suppose now that one end of the string is changed to a free end. The frequency is also changed, but the total length, tension, and linear mass density of the string remains the same. As a result of these changes, the standing wave has 4 antinodes.

What is the new frequency? Show your work.

20. [4 pts] Two in-phase identical sources, labeled A and B, are separated by a distance of 30 cm and produce two-dimensional waves. An observation point is located 16 cm to the right of source B.

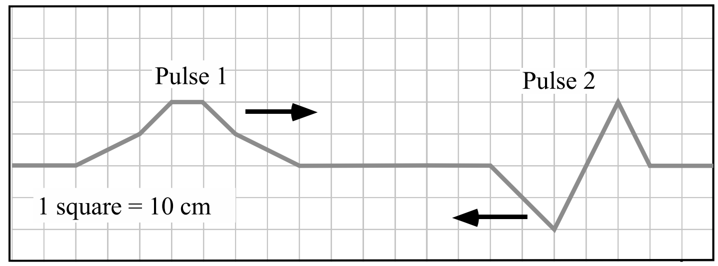
What is the **largest wavelength** of waves that could produce **complete destructive interference** at the observation point? Assume the amplitude of both waves at the observation point are equal. Show your work.

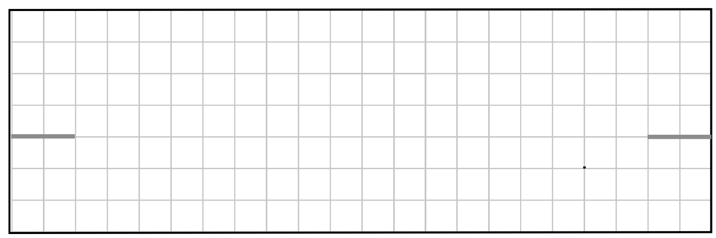


Q21–Q25: Tutorial free response — Unless otherwise noted, explain your reasoning or show your work.

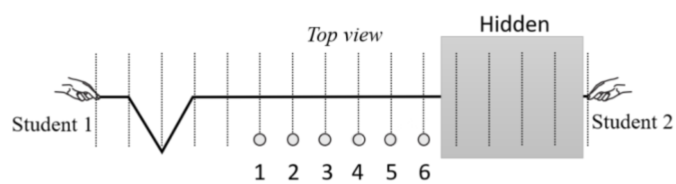
21. [4 pts] Two pulses move towards each other with speed 10 cm/s, as shown below. Each square represents 10 cm.

    On the diagram below right, draw the shape of the spring at the instant $t = 5$ s. No explanation is required.



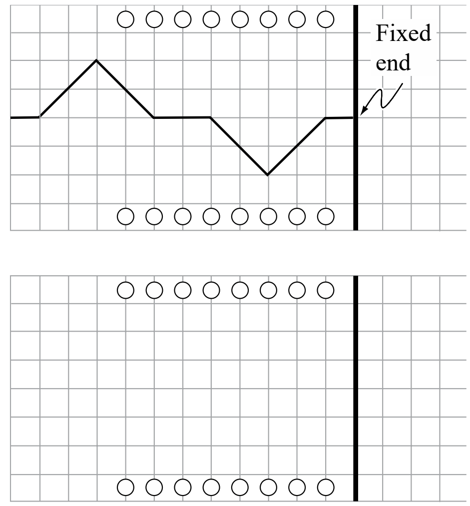


22. [4 pts] Two students hold each end of a stretched spring. Below the stretched spring are six cups. Both students generate a pulse similar in shape, but the pulses are not necessarily generated at the same time. The shape of the spring before the pulses have reached each other, is shown at right (note that any pulse student 2 may have generated is hidden in the image).



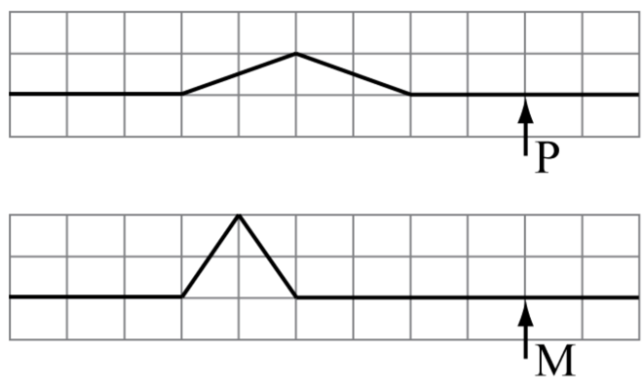
    If all cups except cup 5 are knocked over, was student 2's pulse generated *before*, *after*, or *the same time* as student 1's? If this is not possible or if more information is necessary, state so explicitly. Explain your reasoning.

23. [4 pts] A pulse moves to the right along a spring with a fixed end. Cups are placed on either side of the spring as shown. The maximum transverse displacement of the spring while the pulse approaches the end of the spring is less than the distance from the equilibrium position of the spring to the cups. At the time shown, no part of the pulse has reached the fixed end of the spring.



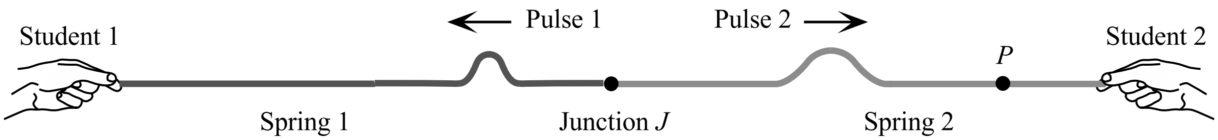
On the diagram at right, mark which (if any) cups are knocked over during the reflection of the pulse from the fixed end. Briefly explain. (You may use the empty grid at right to help you determine your answer, and as part of your explanation, if desired.)

24. [4 pts] Two individual pulses are created in springs 1 and 2. Student A measures the time Δt_A for the pulse in spring 1 to pass point P. (The interval of time begins when the leading edge of the pulse reaches point P and ends when the trailing edge passes point P.) Student B measures the time Δt_B for the pulse in spring 2 to pass point M (using the same criteria).



If $\Delta t_B = 2\Delta t_A$, is the speed of the pulse in spring 1 *greater than, less than*, or *equal to* the speed of the pulse in spring 2? Explain.

25. [4 pts] Two different springs are connected at a junction *J*. Student 1 holds the left end of spring 1 and student 2 holds the right end of spring 2. Only one student creates a pulse. A short time later, the springs have the shapes as shown in the top view diagram. Ignore reflections at the students' hands.



Top view

Which student generated the incident pulse? If there is not enough information to answer, state so explicitly. Explain.