Physics 123A
Autumn 2024

123A - MAJUMDAR

Midterm 1
October 17th, 2024

Please use the boxes below to clearly print your name and UW NetID.
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Do not open the exam until told to do so.
When prompted, clearly print the information required at the top of each page of this exam booklet.
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For questions with multiple correct answers, **you will receive partial credit for each correct answer and you will loose all credit for choosing any incorrect answer**.

I. [45 points total] Lecture Questions (please mark all the correct answers.)

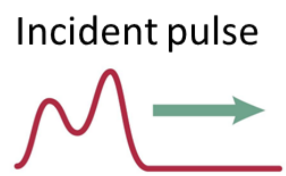
1. [5 points] A 1.0 kg cart on a frictionless track is attached to a horizontal spring with spring constant k = 9.0 N/m. If the cart is displaced 1.0 m from equilibrium and released from rest, what is the cart's maximum velocity?
   A. 9.0 m/s
   B. 3.0 m/s
   C. 4.5 m/s
   D. Not enough information

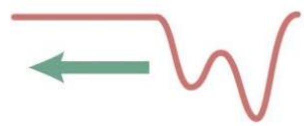
2. [5 points] A simple pendulum is undergoing small-angle oscillations with a frequency f = 0.5 Hz. If the length of the string is increased by a factor of two, the resultant frequency of oscillations
   A. stays the same.
   B. decreases by a factor of 2.
   C. decreases by a factor of 4.
   D. decreases by a factor of $\sqrt{2}$.

3. [5 points] Which of these forces could result in simple harmonic motion? Positive values of $F(x)$ correspond to the forces acting in the positive x direction. Select **all** that apply.
   A. $F(x) = -5x + 8$
   B. $F(x) = 5x$
   C. $F(x) = -5x$
   D. $F(x) = 5x^2$
   E. $F(x) = -5x^2$

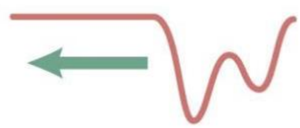
4. [5 points] Consider two systems of a vertical spring and an attached mass. The two springs have identical spring constants. Spring 1 has a ball of mass m hanging from it and spring 2 has a ball of mass $2m$ hanging from it. The two masses are oscillating such that the energies of the two systems are the same. What is the ratio of the oscillation amplitudes: A_1/A_2?
   A. $\frac{1}{\sqrt{2}}$
   B. $\frac{1}{2}$
   C. 1
   D. 2
   E. $\sqrt{2}$

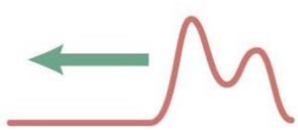
5. [5 points] A rope is attached to a flag pole at a **fixed** point. A pulse traveling rightward is sent along the rope, as shown at right. Which of the following figures show the reflected pulse viewed far away from the flag pole?



   A.


   B.


   C.


   D.


6. [5 points] Consider a harmonic wave traveling on a string. Select **all** of the true statements out of the following options:

   A. The period of oscillations is determined exclusively by the source of the wave.
   B. The period of oscillations is determined by both the source of the wave and the properties of the string.
   C. The speed at which the wave travels along the string is determined exclusively by the properties of the string.
   D. The speed at which the wave travels along the string is determined by both the source of the wave and the properties of the string.
   E. The maximum speed v of a particle on a string is determined by both the source of the wave and the properties of the string.

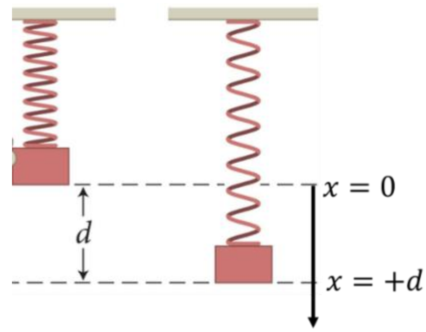
7. [5 points] Which of the following superpositions of two waves will result in a standing wave? Select **all** that apply.

   A. $4\sin(3x - 2t) + 4\sin(3x + 2t)$
   B. $4\sin(3x - 2t) - 4\sin(3x + 2t)$
   C. $4\sin(3x - 2t) + 4\sin(6x + 2t)$
   D. $4\sin(3x - 2t) + 8\sin(3x + 2t)$
   E. $4\sin(3x - 2t) + 4\sin(6x + 4t)$

8. [5 points] A harmonic wave traveling along a light string approaches a splice to a heavier string, as shown. The wave speed in the heavier string is half that in the light string. Select **all** of the following correct statements.

   A. The frequency of oscillation in the heavier string is twice that in the lighter string.
   B. The frequency of oscillation in the heavier string is half that in the lighter string.
   C. The frequency of oscillation in the heavier string is the same as in the lighter string.
   D. The wavelength in the heavier string is twice that in the lighter string.
   E. The wavelength in the heavier string is half that in the lighter string.

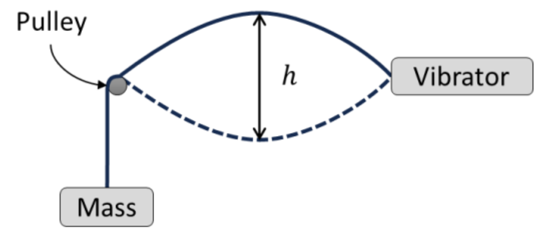
9. [5 points] A mass attached to a vertical spring is pulled down a distance d from the equilibrium position, as shown. The mass is then released from rest at $t = 0s$ and undergoes simple harmonic motion. The **positive x direction is downward** as indicated in the drawing, and the simple harmonic motion can be written as $x(t) = d\sin(\omega t + \phi)$. What is ϕ?

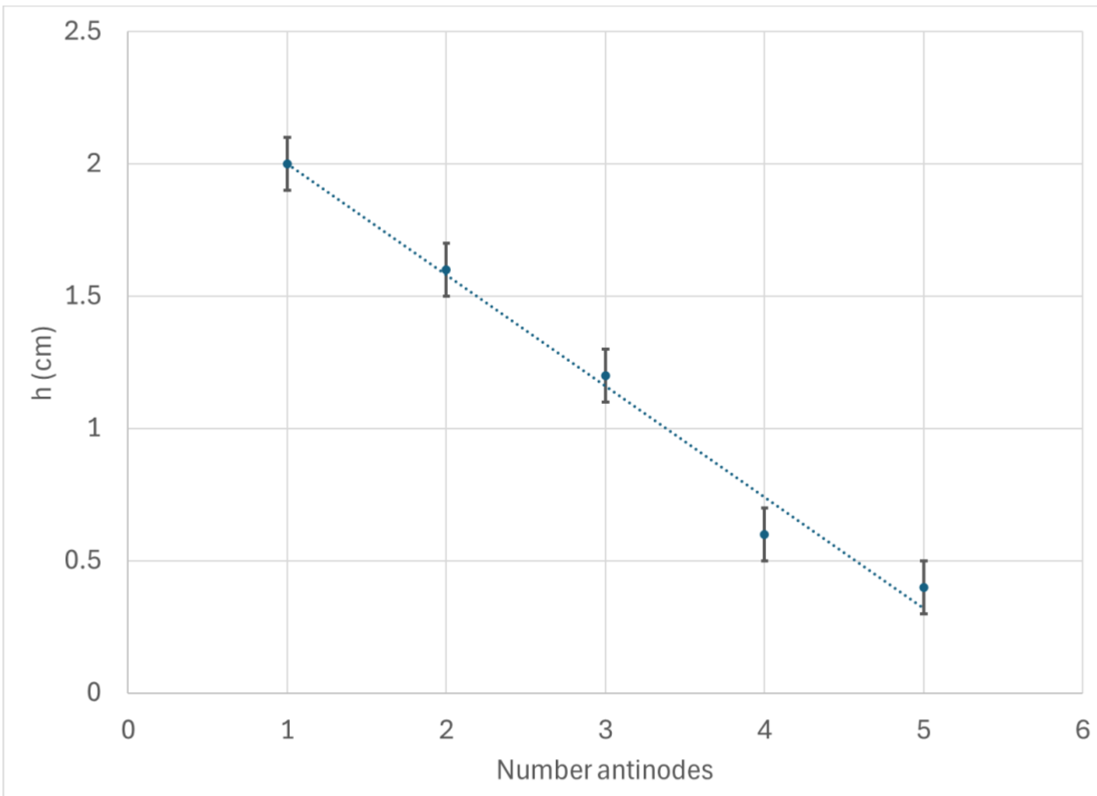


A. $-\pi/2$
B. $-\pi/4$
C. 0
D. $\pi/4$
E. $\pi/2$

II. [15 points total] Lab Questions

A string is attached to a vibrator at one end, and at the other end it hangs over a pulley with a mass attached to the end of the string, as shown on the right. You adjust the frequency of the vibrator until you see one antinode and you measure the height of the antinode, h. You then increase the frequency until you see another antinode and measure the height at the antinode closest to the pulley. You repeat this with increasing numbers of antinodes and produce the graph shown below, which includes a linear trendline.





10. [5 points] Select **all** the following statements that are correct.

A. h is the dependent variable.
B. h is the independent variable.
C. h is a control variable.
D. The number of antinodes is the dependent variable.
E. The number of antinodes is the independent variable.

11. [5 points] All members of your team repeat the measurement of h obtaining the following values: 1.20 cm, 1.45 cm, 1.30 cm, and 1.25 cm. How could your team report the height consistent with the rules used in this class?

    A. 1.30 ± 0.005 cm
    B. 1.30 ± 0.15 cm
    C. 1.30 ± 0.1 cm
    D. 1.3 ± 0.15 cm
    E. 1.3 ± 0.1 cm

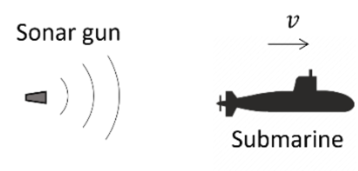
12. [5 points] Which of the following best matches the conclusion you could reach from only your data? Select **all** that apply.

    A. The trendline is **a good fit** to your data as it goes through 2/3rd of the uncertainty bars.
    B. The trendline is **not a good fit** to your data as it does not go through all the uncertainty bars.
    C. If the trendline were a good fit we could conclude that there is a linear relationship between h and the number of antinodes.
    D. If the trendline were a good fit we could conclude that there is a linear relationship between $1/h$ and the number of antinodes.

III. [25 points total] Lecture Free Response Questions
You must show your work to get the full credit.

13. [5 points] During a fire drill in your dormitory, you notice that the sound waves from the two alarms on your floor interfere with each other, and you hear four beats every two seconds. If the average of the two frequencies is 3500 Hz, what are the frequencies of the two alarms?

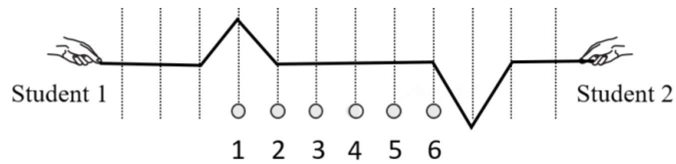
14. [10 points] The speed of a submarine is measured with a stationary underwater sonar gun. The gun emits sound waves that reflect off the submarine and return to the gun. The frequency of the sound waves emitted by the gun is 120 kHz, and the submarine is moving away from the sonar gun at a speed of $v = 12.0$ m/s. What is the frequency of the sound waves detected by the gun? Note that the speed of sound in water is 1480 m/s.



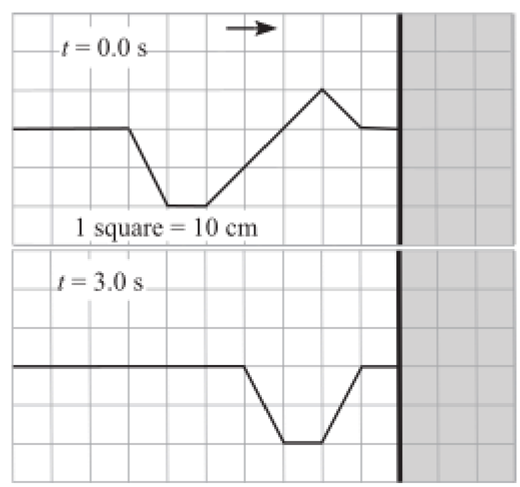
15. [10 points] A spring has an equilibrium length of L. Consider the following two cases. In case A you stretch the spring to a length of $2L$, and it takes time t_{A} for a pulse to travel the whole length of $2L$. In case B you stretch the spring to a length of $3L$, and it takes time t_{B} for a pulse to travel the whole length of $3L$. What is the value of the ratio $t_{\mathrm{B}}/t_{\mathrm{A}}$? Hint: The tension in the spring is proportional to the elongation, and thus for case B the tension in the spring is twice that for case A.

IV. [15 points total] Tutorial Free Response Questions

16. [7 points] Students 1 and 2 each generate a single transverse pulse by moving the ends of a spring at *unknown* times. Originally, there was a line of cups, numbered 1 to 6, below the spring, as shown on the right. In the time for the pulses to travel to the end of the spring, which of the cups are knocked over? Explain your reasoning.



17. [8 points] A pulse moves with a speed of 10 cm/s to the right along a spring. The shapes of the spring at times $t = 0.0$ s and $t = 3.0$ s are shown on the right. Is the right end of the spring a *fixed end*, *free end,* or *not possible to determine*? Explain your reasoning.



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Constants

Speed of light	$c_0 = 3.0 \times 10^8\,\mathrm{m/s}$
Speed of sound	$c = 342\,\mathrm{m/s}$
Gravitational acceleration	$g = 9.8\,\mathrm{m/s^2}$
Plank's constant	$h = 6.626 \times 10^{-34}\,\mathrm{J \cdot s}$
Boltzmann constant	$k_\mathrm{B} = 1.381 \times 10^{-23}\,\mathrm{J/K}$
Avogadro's number	$N_\mathrm{A} = 6.022 \times 10^{23}\,\mathrm{mol^{-1}}$
Atmospheric pressure	$P_\mathrm{atm} = 101.3 \times 10^3\,\mathrm{Pa}$

Mathematics

Standard deviation	$s = \sqrt{\dfrac{\Sigma_{i=1}^{n} \left(x_i - x_\mathrm{ave}\right)^2}{n-1}}$

Equations from 121

Constant acceleration (x dir.)	$x_f = x_i + v_{x,i}\Delta t + \frac{1}{2}a_x \Delta t^2$
	$v_{x,f} = v_{x,i} + a_x \Delta t$
Kinetic energy	$K = \frac{1}{2}mv^2$
Equation of motion	$\vec{a} = \dfrac{\sum \vec{F}}{m}$

Periodic motion

Frequency	$f \equiv \dfrac{1}{T}$
Angular frequency	$\omega = 2\pi f$
SHM displacement	$x(t) = A\sin\left(\omega t + \phi_i\right)$
SHM equation	$\dfrac{d^2 x}{dt^2} = -\omega^2 x$
SHM mechanical energy	$E = K + U = \dfrac{1}{2}m\omega^2 A^2$
Fourier's theorem: sum of sinusoidal functions with frequency	$f_n = \dfrac{n}{T}$

Natural angular frequency:

mass on a spring	$\omega = \sqrt{\dfrac{k}{m}}$
torsion oscillator	$\omega = \sqrt{\dfrac{\kappa}{I}}$
pendulum	$\omega = \sqrt{\dfrac{ml_\mathrm{cm}g}{I}}$
simple pendulum	$\omega = \sqrt{\dfrac{g}{l}}$
Damped energy	$E(t) = E_0 e^{-t/\tau}$

Waves in one dimension

Wave number	$k = \dfrac{2\pi}{\lambda}$
Wave speed	$c = \lambda f = \dfrac{\omega}{k}$
Harmonic wave going in x dir.	$D_y = A\sin\left(kx - \omega t + \phi_i\right)$
Standing wave fixed at ends	$D_y = 2A\sin\left(kx\right)\cos\left(\omega t\right)$
Linear density	$\mu = \dfrac{m}{l}$
Wave speed on string	$c = \sqrt{\dfrac{\mathcal{T}}{\mu}}$
Power harmonic wave on string	$P_\mathrm{av} = \frac{1}{2}\mu A^2 \omega^2 c$
Wave equation	$\dfrac{\partial^2 f}{\partial x^2} = \dfrac{1}{c^2}\dfrac{\partial^2 f}{\partial t^2}$

Waves in two and three dimension

Amplitude surface waves	$A \propto \dfrac{1}{\sqrt{r}}$
Amplitude spherical waves	$A \propto \dfrac{1}{r}$
Intensity of spherical wave	$I \equiv \dfrac{P}{A}$
Intensity of surface wave	$I_\mathrm{surf} \equiv \dfrac{P}{L}$
Intensity level	$\beta = (10\,\mathrm{dB})\log\left(\dfrac{I}{10^{-12}\,\mathrm{W \cdot m^{-2}}}\right)$
Beating wave	$D_x = 2A\cos\left(\pi f_\mathrm{beat} t\right)\sin\left(2\pi f_\mathrm{av} t\right)$
Beat frequency	$f_\mathrm{beat} = \lvert f_1 - f_2 \rvert$
Average frequency	$f_\mathrm{av} = \frac{1}{2}\left(f_1 + f_2\right)$
Doppler effect	$f_\mathrm{o} = \dfrac{c \pm v_\mathrm{o}}{c \pm v_\mathrm{s}} f_\mathrm{s}$
Shock wave angle	$\sin\theta = \dfrac{c}{v_\mathrm{s}}$