Physics 116 B
Spring 2025

116B - MORALES

Midterm 1
April 29th, 2025

Please use the boxes below to clearly print your name and UW NetID.
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Clearly fill out this cover page and the top portion of the provided bubble sheet with the necessary information.

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.
You can remove the equation sheet(s). Otherwise, keep the exam booklet intact.
You will have 60 minutes to complete the examination.

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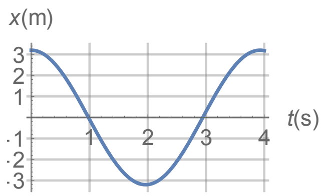
I. Lecture Multiple Choice [60 pts]. **Choose only one answer for each question, circle your answer in this booklet, and fill it out on your bubble sheet.**

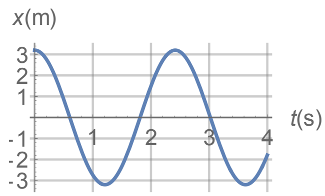
Use the following situation to answer the next three questions:

An ideal spring of stiffness 5.0 N/m is connected to a block of mass 2.0 kg. The other end of the spring is fastened to a wall and the block is free to move over a horizontal smooth surface. Initially the spring is compressed by a distance of 3.2 m from its equilibrium position in the $+x$-direction and is then allowed to oscillate.

1. [5 pts] From the graphs below, choose the one representing the block's displacement from equilibrium as a function of time.



A.



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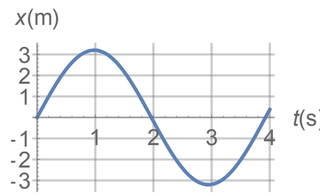

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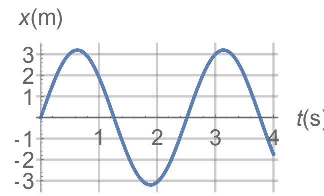

D.

2. [5 pts] What is the maximum kinetic energy of the block?

   A. 10 J

   B. 15 J

   C. 26 J

   D. 34 J

   E. Information provided is not enough to answer.

3. [5 pts] Which one of the following on its own would double the period of oscillation T?

   A. Doubling the amplitude.

   B. Quadrupling the mass of the block.

   C. Quadrupling the stiffness (spring constant).

   D. Doubling the mass of the block.

   E. Doubling the stiffness (spring constant).

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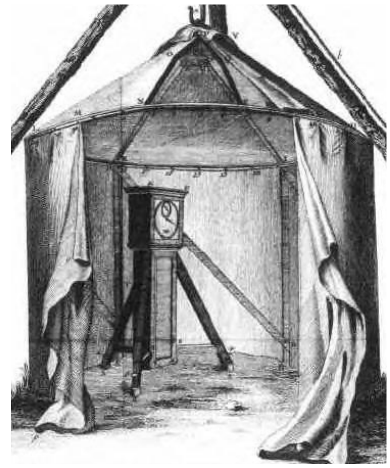
Use the following situation to answer the next two questions:

While we tend to think of grandfather clocks as antiques, for several hundred years they were precise scientific instruments for measuring time. The engraving at right depicts the clock used in Cook's 1769 observation in Tahiti of the transit of Venus across the sun. (Rich people bought and displayed grandfather clocks to show how modern, educated, and scientific they were.)



4. [5 pts] Most grandfather clocks use a pendulum with a 2 second period: a swing one direction takes 1 second (tick), and the return swing (tock) takes another second. How long is the pendulum to achieve that?

   A. 0.993 meters

   B. 25 cm

   C. 1.007 meters

   D. $2\pi\sqrt{m/g}$

   E. It can be any be any length.

5. [5 pts] Grandfather clocks require power to keep running (usually provided by weights). If you turn off the power, the swing of the pendulum will slowly become smaller and eventually cease. If it takes around 10 minutes (600 seconds) for the pendulum swing to become half as large, which of the following equations best describes the motion of the undriven pendulum. [A_0 is the initial amplitude measured in radians, and t is measured in seconds.]

   A. $\theta(t) = A_0 e^{-t/(865.8\text{ s})}\cos(4\pi\text{ s}^{-1}t)$

   B. $\theta(t) = A_0 e^{-t/(600\text{ s})}\cos(4\pi\text{ s}^{-1}t)$

   C. $\theta(t) = A_0 e^{-t/(10\text{ s})}\cos(\pi\text{ s}^{-1}t)$

   D. $\theta(t) = A_0 e^{-t/(865.8\text{ s})}\cos(\pi\text{ s}^{-1}t)$

   E. $x(t) = A_0\cos(4\pi\text{ s}^{-1}t)$

6. [5 pts] Most animals walk with a gait associated with the physical pendulum frequency of their legs. Giraffes, famously, have very long legs. Use a simple model for a leg as a rod of uniform mass m and length L. Which of the following statements describes the frequency of a giraffe's gait f_g compared to the walking gait of a human f_h? *Hint*: the moment of inertia of a rod-like physical pendulum is $I = mL^2/3$.

   A. $f_h > f_g$; the key equation is $f = \frac{1}{2\pi}\sqrt{\frac{mgL}{2}}$ so the longer the leg the lower the frequency.

   B. $f_h < f_g$; the key equation is $f = \frac{1}{2\pi}\sqrt{\frac{mgL}{2I}}$ so the longer the leg the higher the frequency.

   C. $f_h > f_g$; the key equation is $f = \frac{1}{2\pi}\sqrt{\frac{3g}{2L}}$ so the longer the leg the lower the frequency.

   D. $f_h < f_g$; the key equation is $f = \frac{1}{2\pi}\sqrt{\frac{3g}{2L}}$ so the longer the leg the higher the frequency.

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Use the following situation to answer the next two questions:
A transverse sinusoidal wave is traveling on a string to the right (in the $+x$-direction) at a speed of 7.3 $\mathrm{m/s}$. The wave's maximum displacement from equilibrium is 9.0 m. Assume there is no damping.

7. [5 pts] Which one of the following represents this wave?

   A. $y(x,t) = (9.0\ \mathrm{m})\cos(2.6\ \mathrm{m}^{-1}x + 19\ \mathrm{s}^{-1}\ t)$

   B. $y(x,t) = (9.0\ \mathrm{m})\sin(-2.6\ \mathrm{m}^{-1}x + 19\ \mathrm{s}^{-1}\ t)$

   C. $y(x,t) = (9.0\ \mathrm{m})\cos(19\ \mathrm{m}^{-1}x - 2.6\ \mathrm{s}^{-1}\ t)$

   D. $y(x,t) = (9.0\ \mathrm{m})\cos(2.6\ \mathrm{s}^{-1}\ t - 19\ \mathrm{m}^{-1}x)$

   E. $y(x,t) = (9.0\ \mathrm{m})\sin(2.6\ \mathrm{m}^{-1}x + 19\ \mathrm{s}^{-1}\ t)$

8. [5 pts] If we replace the string with one having 3 times the linear mass density, by what factor should we change the tension compared to the previous case so that speed of the wave is doubled?

   A. 3/2

   B. 3/4

   C. 2

   D. 6

   E. 12

9. [5 pts] The big bang was the event considered to be the start of the known universe. It has an observable remnant in the form of an electromagnetic radiation that has a peak wavelength of about 2 mm. Calculate the corresponding frequency.

   A. $1.5 \times 10^{11}\mathrm{Hz}$

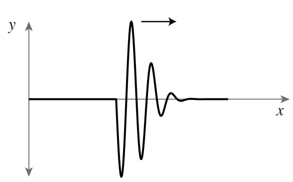
   B. $3.0 \times 10^{11}\mathrm{Hz}$

   C. $5.0 \times 10^{11}\mathrm{Hz}$

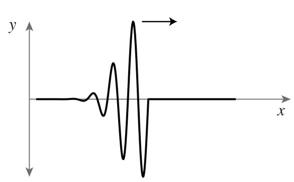
   D. $7.5 \times 10^{11}\mathrm{Hz}$

   E. $1.0 \times 10^{12}\mathrm{Hz}$

10. [5 pts] The graph at right shows the **<u>history</u>** graph of a wave moving in the $+x$ direction. Which of the below **<u>snapshot</u>** graphs corresponds to this history graph?



A.



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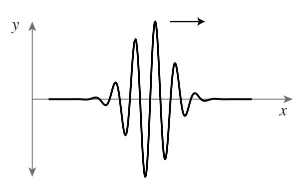

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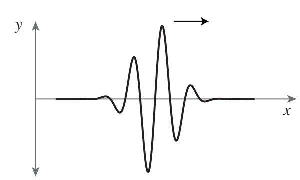
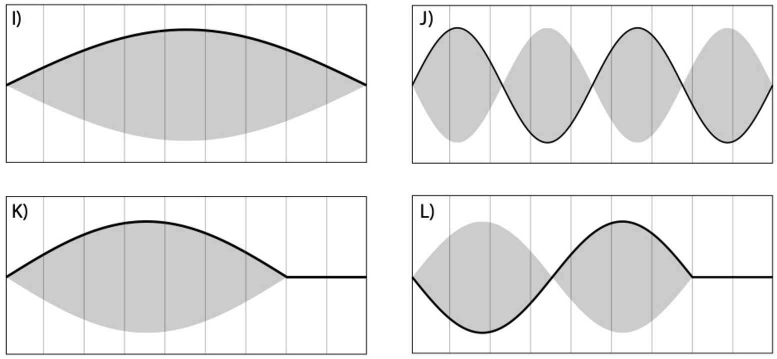


D.

Use the following situation to answer the next two questions:
Below is a diagram of standing waves trapped on a guitar string, labelled with letters I, J, K, L.
All waves are on the same string with the same tension, a finger is used on a fret to pinch the string in some of the diagrams.



11. [5 pts] Which one of the following statements accurately describe the pitch (frequency) f of the trapped waves and their properties.

    A. f depends on wavelength, with $f_J < f_L < f_K < f_I$.

    B. f depends on wavelength, with $f_I < f_K < f_L < f_J$.

    C. f depends on the trap's length, with $f_K < f_L < f_I < f_J$.

    D. f depends on which fret is used to hold the string, with $f_I < f_J < f_K < f_L$.

12. [5 pts] Consider standing wave J in the diagram. If the tension in the string is increased by a factor of 2 while keeping the length of the string and the frequency the same as before, how many modes would you observe?

    A. 1

    B. 2

    C. 4

    D. 8

    E. No modes are observed.

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II. Lecture Free Response [20 pts] **Show your work for full credit.**
A firetruck is sounding its sirens at a frequency of 900 Hz. You are standing 100 meters from the firetruck, and you measure the intensity of the sound to be $1.0 \times 10^{-2}\mathrm{W/m^2}$. The firetruck is moving in your direction.

13. [5 pts] Calculate the total power produced by the firetruck's siren.

14. [4 pts] What is the sound intensity level β you experience when the firetruck is 100 meters away from you?

15. [5 pts] As the firetruck approaches you, you measure the frequency of its siren to be 990 Hz. How fast is the firetruck moving? Take the speed of sound to be 343 m/s.

16. [6 pts] Now the firetruck is 10 meters away from you. What is the sound intensity level β you experience?

III. Tutorial Free-Response [20 pts]. **Explain your reasoning where stated to get full credit.**
A block of mass m on a frictionless surface is attached to an ideal massless spring, as shown in figure 1. The spring, which has spring constant k, is fixed to the wall. The dashed line indicates the position of the right edge of the spring when the spring is neither stretched nor compressed and the block is at its equilibrium position.

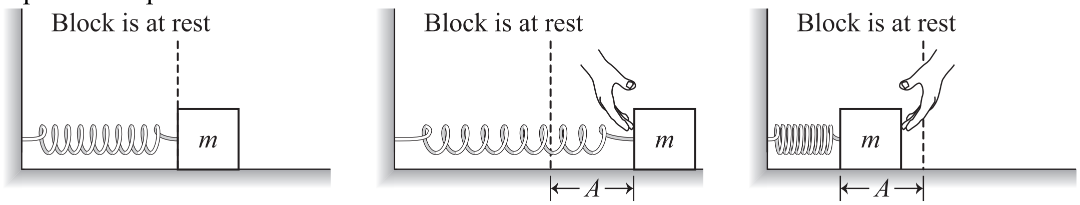


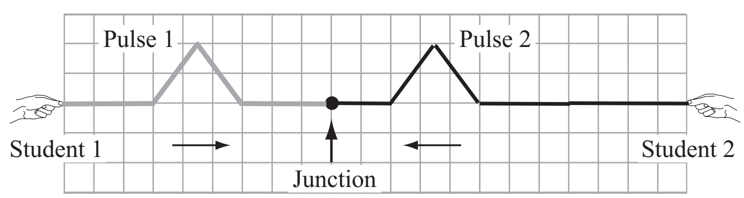
Figure 1 Figure 2 Figure 3

Figures 2 and 3 show the block held in place a distance A to the right and left of the equilibrium position, respectively.

17. [6 pts] In which direction is the net force on the block when it is held in place as shown in figure 2? Explain.

18. [4 pts] Suppose the hand in figure 2 were suddenly removed. After the hand is removed, how would the force on the block by the spring be related to the net force on the block? No explanation needed.

Two different springs are joined together. Two students pull on either side to create tension in the combined springs. At time $t = t_0$ each of the two students creates a pulse by moving their hand up and then down. The snapshot at right is taken at a later time $t = t_1$.



19. [4 pts] Is the speed of the pulse on the left spring *greater than*, *less than* or *equal to* the speed of the pulse on the right spring? No explanation needed.

20. [6 pts] Was the time needed to create Pulse 1 *greater than*, *less than* or *equal to* the time needed to create Pulse 2? Explain briefly. If there is not enough information to answer, state the additional information needed to answer.

Phys 116, Equation Sheet, Midterm 1

Constants and Conversions

Free-fall acceleration	$g = 9.80\ m/s^2$
Newton	$1\ \mathrm{N} = 1\ \mathrm{kg\ m/s^2}$
Boltzmann's constant	$k_\mathrm{B} = 1.38 \times 10^{-23}\mathrm{J/K}$
Gas constant	$R = N_\mathrm{A} k_\mathrm{B} = 8.31\ \mathrm{J/(mol \cdot K)}$
Minimum sound intensity	$I_0 = 1 \times 10^{-12}\mathrm{W/m^2}$

Mathematics

Components of a 2D vector $\vec{A}$	$A_x = A\cos\theta,\quad A_y = A\sin\theta$
Magnitude and direction of $\vec{A}$ relative to x-axis	$A = \sqrt{A_x^2 + A_y^2},\quad \theta = \tan^{-1}(A_y/A_x)$
Volume & surface area of a sphere	$V = \frac{4}{3}\pi r^3,\quad A = 4\pi r^2$

Equations from 114 and 115

Kinematics (const. accel. a)	$(v_x)_\mathrm{f} = (v_x)_\mathrm{i} + a_x t$ $x_\mathrm{f} = x_\mathrm{i} + (v_x)_\mathrm{i} t + \frac{1}{2}at^2$ $(v_x)_\mathrm{f}^2 = (v_x)_\mathrm{i}^2 + 2a_x\Delta x$
Newton's Laws	$\vec{F}_\mathrm{net} = \sum\vec{F} = m\vec{a},\quad \vec{F}_{12} = -\vec{F}_{21}$
Weight	$w = mg$
Work due to a constant force	$W = F_\parallel d = Fd\cos\theta$
Conservation of energy	$\Delta E = W$
Power	$P = \Delta E/\Delta t = W/t = Fv$
Kinetic energy	$K = \frac{1}{2}mv^2$
Elastic potential energy	$\Delta U_\mathrm{s} = \frac{1}{2}k(x_\mathrm{f}^2 - x_\mathrm{i}^2)$
Gravitational potential energy	$U_\mathrm{g} = mgy$
Momentum	$\vec{p} = m\vec{v}$
Torque	$\tau = rF\sin\phi$
Pressure	$p = F/A$
Hooke's Law	$(F_\mathrm{spring})_x = -kx$

Oscillations

Frequency	$f = \dfrac{1}{T}$
Angular frequency	$\omega = \dfrac{2\pi}{T} = 2\pi f = \sqrt{k/m}$
Position in SHM	$x(t) = A\cos(2\pi f t)$
Velocity in SHM	$v_x(t) = -2\pi f A\sin(2\pi f t)$
Acceleration in SHM	$a_x(t) = -(2\pi f)^2 A\cos(2\pi f t)$
SHM max velocity	$\lvert v_\mathrm{max}\rvert = A\omega$
SHM max acceleration	$\lvert a_\mathrm{max}\rvert = A\omega^2$
Mechanical energy in SHM	$E = K + U$ $E = \dfrac{1}{2}kA^2 = \dfrac{1}{2}mv_\mathrm{max}^2$

Frequency and Period

Freq. of Mass on a spring	$f = \dfrac{1}{2\pi}\sqrt{\dfrac{k}{m}}$
Period of Mass on a spring	$T = 2\pi\sqrt{\dfrac{m}{k}}$
Freq. of Simple pendulum	$f = \dfrac{1}{2\pi}\sqrt{\dfrac{g}{L}}$
Period of Simple pendulum	$T = 2\pi\sqrt{\dfrac{L}{g}}$
Freq. of Physical pendulum	$f = \dfrac{1}{2\pi}\sqrt{\dfrac{mgd}{I}}$
Period of Physical pendulum	$T = 2\pi\sqrt{\dfrac{I}{mgd}}$

Damped Oscillation

Amplitude envelope	$x_\mathrm{max}(t) = Ae^{-t/\tau}$

Phys 116, Equation Sheet, Midterm 1

Waves and Sound

Sinusoidal wave function	$y(x,t) = A\cos\left(2\pi\frac{x}{\lambda} \pm 2\pi\frac{t}{T}\right)$
Speed of sinusoidal waves	$v = \lambda f$
Speed of a wave on a string	$v_{\text{string}} = \sqrt{T_s/\mu}$
Linear mass density	$\mu = m/L$
Speed of sound in gas	$v_{\text{sound}} = \sqrt{\frac{\gamma k_{\text{B}} T}{m}}$
	$v_{\text{sound}} = \sqrt{\frac{\gamma R T}{M}}$
Conversion from Celsius to Kelvin	$T = T_{\text{C}} + 273$
Sound intensity	$I = \frac{P}{a}$
Sound Intensity level	$\beta = (10\ \text{dB})\log_{10}\left(\frac{I}{I_0}\right)$
Moving source	$f_{\pm} = \frac{f_{\text{s}}}{1 \mp v_{\text{s}}/v}$
Moving observer	$f_{\pm} = \left(1 \pm \frac{v_0}{v}\right) f_{\text{s}}$
Moving object reflection	$\Delta f = \pm 2 f_{\text{s}} \frac{v_0}{v} \quad \text{for } v_0 \ll v$

Standing waves

On a string

$$f_m = m\left(\frac{v}{2L}\right) = m f_1$$

$$\lambda_m = \frac{\lambda_1}{m} = \frac{2L}{m}, \quad m = 1,2,3,\ldots$$

Open-open or closed-closed pipe

$$f_m = m\left(\frac{v}{2L}\right) = m f_1$$

$$\lambda_m = \frac{\lambda_1}{m} = \frac{2L}{m}, \qquad m = 1,2,3,..$$

Open-closed pipe

$$f_m = m\left(\frac{v}{4L}\right) = m f_1$$

$$\lambda_m = \frac{\lambda_1}{m} = \frac{4L}{m}, \quad m = 1,3,5,\ldots$$