Directions: No books or notes may be used during this exam. Important formulas are provided for you. Graphing calculators and palm top or laptop computers are not allowed. Write everything on the exam booklet provided. Always include three significant digits in your numerical answers.

\[ \vec{F}_s = -k \vec{x} \quad \vec{x}(t) = A \cos(\omega t + \phi_0) = a \sin(\omega t) + b \cos(\omega t) \quad \omega = \sqrt{\frac{k}{m}} \quad U_s = \frac{1}{2} kx^2 \quad \omega = 2\pi f \quad T = \frac{1}{f} \]

\[ \sin \theta \equiv \tan \theta \equiv \theta \quad \omega = \sqrt{\frac{g}{L}} \quad \vec{F}_d = -b \vec{v} \quad \vec{x}(t) = Ae^{-\alpha t} \cos(\omega' t) \quad \alpha = \frac{b}{2m} \quad \omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}} \]

\[ v = \lambda f = \frac{\omega}{k} \quad I = \frac{p}{a} \quad \nu = (331 + 0.6T) \quad \beta = 10 \log_{10} \left( \frac{I}{I_o} \right) \quad I_o = 1.00 \times 10^{-12} \text{ W/m}^2 \quad f = \frac{(\nu + \nu_s)}{(\nu - \nu_s)} \]

\[ k = \frac{2\pi}{\lambda} \quad \Delta r = m\lambda \quad \Delta r = (m + \frac{1}{2})\lambda \quad m \in \{0, 1, 2, 3, \ldots\} \quad f_{\text{beat}} = |f_1 - f_2| \quad n = \frac{c}{v} \]

\[ \lambda_m = \frac{2L}{m} \quad f_m = \frac{mv}{2L} \quad m \in \{1, 2, 3, \ldots\} \quad \lambda_m = \frac{4L}{m} \quad f_m = \frac{mv}{4L} \quad m \in \{1, 3, 5, \ldots\} \]

\[ d \sin \theta_m = m\lambda \quad d \sin \theta_m = (m + \frac{1}{2})\lambda \quad a \sin \theta_p = p\lambda \quad a \sin \theta_p = (p + \frac{1}{2})\lambda \]

Question 1: WRITE THE FORM DESIGNATOR FOR THIS EXAM (A) IN THE ANSWER BOX FOR QUESTION #1 ON THE FIRST PAGE OF THE EXAM BOOKLET.

Questions 2-6 (5 points each) Multiple Choice. You will be graded on your answer only. It is not necessary to show your work for these problems. Put the answer for each question in the proper numbered box on the first page of your test booklet.

2. What is diffraction? (A) Waves spread out because they have different wavelengths. (B) Waves spread out after going through an opening in a barrier. (C) Waves combine to make larger or smaller waves.

3. In an active sonar experiment, the outgoing sound wave has a frequency of 48.0 kHz, the reflected sound wave has a frequency of 52.0 kHz, and the speed of sound in the medium carrying the sound wave is 400 m/s. With respect to the medium, how fast is the object moving off of which the sound wave reflected? (A) 4.00 m/s (B) 8.00 m/s (C) 16.0 m/s (D) 100 m/s (E) 400 m/s (F) 1600 m/s (G) There isn't enough information given to answer.

4. In the fundamental mode of oscillation of a wave on a guitar string, the wavelength is 1.20 m, the frequency is 250 Hz, and the speed of the wave is 300 m/s. What would be the wavelength of the fundamental mode if the speed was increased to 600 m/s? (A) 0.300 m (B) 0.600 m (C) 2.40 m (D) 4.80 m (E) 250 m (F) 600 m (G) None of the above.

5. What causes beats? (A) time-like interference of two waves with the same frequency (B) time-like interference of two waves with different frequencies (C) the Doppler effect when both the source and observer are moving (D) variations in the pressure of a medium due to changes in its density.

6. If the intensity of a wave doubles, then what happens to its intensity level? (A) It doubles also. (B) It increases by a factor of ten. (C) It increases by a factor of one hundred. (D) It increases by 1 decibel. (E) It increases by 2 decibels. (F) It increases by 3 decibels. (G) It increases by 10 decibels.

TURN THE PAGE OVER
Solve the following three problems on the front of the next three pages of your exam booklet. Solve each problem on a separate page, in numerical order. For full credit, include the following:

1. Translate the problem statement from English into math. Write equations of the form "symbol equals number units". Include such equations for any constants used in the solution. Write "symbol equals ?" to indicate which quantity is to be determined.
2. Draw the physical representations (graph, diagram, free-body diagram, etc.). Include coordinate axis, if appropriate. Give each axis a label and indicate positive and negative directions, if appropriate.
3. Solve for the unknown quantity. For full credit, include the only mathematical representations which are used in the solution from the list of formulas on the other side of this exam.

7. (25 pts.) **Determining Mass**

A spring oscillates with a period of 2.00 s when a block of mass \( m \) is attached to it and the other end is attached to a large, immovable object. When the mass is increased by 2.00 kg, the period of oscillation is 3.00 s. Determine the mass \( m \). Assume that friction and air resistance are negligible and that the mass moves on a flat, horizontal surface.

8. (25 pts.) **Constructive Interference**

One speaker is located at \((x, y) = (-1.00 \text{ m}, 0 \text{ m})\) and the other is located at \((x, y) = (0 \text{ m}, 3.00 \text{ m})\). The speakers emit identical sound waves of wavelength 2.00 m which are initially in phase. Where on the positive x-axis does constructive interference occur? For full credit, follow the directions.

9. (25 pts.) **Diffraction Grating**

Light of a single wavelength passes perpendicularly through a diffraction grating. The first-order bright fringe in the interference pattern on a screen is at an angle of 11.3 degrees. The screen and diffraction grating are parallel to each other. At what angle is the fourth-order bright fringe in the interference pattern on the screen?

**WHEN YOU TURN IN YOUR EXAM, SHOW YOUR I.D. CARD AND SIGN THE CLASS LIST.**
Directions: No books or notes may be used during this exam. Important formulas are provided for you. Graphing calculators and palmtop or laptop computers are not allowed. Write everything on the exam booklet provided. Always include three significant digits in your numerical answers.

$$\vec{F}_s = -k\vec{v}$$  $$\vec{x}(t) = A\cos(\omega t + \phi_s) = a\sin(\omega t) + b\cos(\omega t)$$  $$\omega = \sqrt{\frac{k}{m}}$$  $$U_s = \frac{1}{2}kx^2$$  $$\omega = 2\pi f$$  $$T = \frac{1}{f}$$

$$\sin \theta \equiv \tan \theta \equiv \theta$$  $$\omega = \sqrt{\frac{g}{L}}$$  $$\vec{F}_D = -b\vec{v}$$  $$\vec{x}(t) = Ae^{-\alpha t}\cos(\omega' t)$$  $$\alpha = \frac{b}{2m}$$  $$\omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$$

$$v = \lambda f = \frac{\omega}{k}$$  $$I = \frac{P}{a}$$  $$v = (331 + 0.6T_C)$$  $$\beta = 10\log_{10}\left(\frac{I}{I_0}\right)$$  $$I_0 = 1.00 \times 10^{-12} \text{ W/m}^2$$  $$f = f \left(\frac{v \pm v_s}{v}\right)$$

$$k = \frac{2\pi}{\lambda}$$  $$\Delta r = m\lambda$$  $$\Delta r = \left(m + \frac{1}{2}\right)\lambda$$  $$m \in \{0, 1, 2, 3, \ldots\}$$  $$f_{\text{beat}} = \left|f_1 - f_2\right|$$  $$n = \frac{c}{v}$$

$$\lambda_m = \frac{2L}{m}$$  $$f_m = \frac{mv}{2L}$$  $$m \in \{1, 2, 3, \ldots\}$$  $$\lambda_m = \frac{4L}{m}$$  $$f_m = \frac{mv}{4L}$$  $$m \in \{1, 3, 5, \ldots\}$$

$$d \sin \theta_m = m\lambda$$  $$d \sin \theta_m = \left(m + \frac{1}{2}\right)\lambda$$  $$a \sin \theta_p = p\lambda$$  $$a \sin \theta_p = (p + \frac{1}{2})\lambda$$

Question 1: WRITE THE FORM DESIGNATOR FOR THIS EXAM (B) IN THE ANSWER BOX FOR QUESTION #1 ON THE FIRST PAGE OF THE EXAM BOOKLET.

Questions 2-6 (5 points each) Multiple Choice. You will be graded on your answer only. It is not necessary to show your work for these problems. Put the answer for each question in the proper numbered box on the first page of your test booklet.

2. If the intensity of a wave doubles, then what happens to its intensity level? (A) It doubles also. (B) It increases by a factor of ten. (C) It increases by a factor of one hundred. (D) It increases by 1 decibel. (E) It increases by 2 decibels. (F) It increases by 3 decibels. (G) It increases by 10 decibels.

3. What is diffraction? (A) Waves spread out because they have different wavelengths. (B) Waves spread out after going through an opening in a barrier. (C) Waves combine to make larger or smaller waves.

4. In an active sonar experiment, the outgoing sound wave has a frequency of 48.0 kHz, the reflected sound wave has a frequency of 52.0 kHz, and the speed of sound in the medium carrying the sound wave is 400 m/s. With respect to the medium, how fast is the object moving off of which the sound wave reflected? (A) 4.00 m/s (B) 8.00 m/s (C) 16.0 m/s (D) 100 m/s (E) 400 m/s (F) 1600 m/s (G) There isn't enough information given to answer.

5. In the fundamental mode of oscillation of a wave on a guitar string, the wavelength is 1.20 m, the frequency is 250 Hz, and the speed of the wave is 300 m/s. What would be the wavelength of the fundamental mode if the speed was increased to 600 m/s? (A) 0.300 m (B) 0.600 m (C) 2.40 m (D) 4.80 m (E) 250 m (F) 600 m (G) None of the above.

6. What causes beats? (A) time-like interference of two waves with the same frequency (B) time-like interference of two waves with different frequencies (C) the Doppler effect when both the source and observer are moving (D) variations in the pressure of a medium due to changes in its density.

TURN THE PAGE OVER
Solve the following three problems on the front of the next three pages of your exam booklet. Solve each problem on a separate page, in numerical order. For full credit, include the following:

1. Translate the problem statement from English into math. Write equations of the form "symbol equals number units". Include such equations for any constants used in the solution. Write "symbol equals ?" to indicate which quantity is to be determined.
2. Draw the physical representations (graph, diagram, free-body diagram, etc.). Include coordinate axis, if appropriate. Give each axis a label and indicate positive and negative directions, if appropriate.
3. Solve for the unknown quantity. For full credit, include the only mathematical representations which are used in the solution from the list of formulas on the other side of this exam.

7. (25 pts.) Determining Mass

A spring oscillates with a period of 2.00 s when a block of mass $m$ is attached to it and the other end is attached to a large, immovable object. When the mass is increased by 2.00 kg, the period of oscillation is 3.00 s. Determine the mass $m$. Assume that friction and air resistance are negligible and that the mass moves on a flat, horizontal surface.

8. (25 pts.) Constructive Interference

One speaker is located at $(x, y) = (-1.00 \text{ m}, 0 \text{ m})$ and the other is located at $(x, y) = (0 \text{ m}, 3.00 \text{ m})$. The speakers emit identical sound waves of wavelength 2.00 m which are initially in phase. Where on the positive $x$-axis does constructive interference occur? For full credit, follow the directions.

9. (25 pts.) Diffraction Grating

Light of a single wavelength passes perpendicularly through a diffraction grating. The first-order bright fringe in the interference pattern on a screen is at an angle of 11.3 degrees. The screen and diffraction grating are parallel to each other. At what angle is the fourth-order bright fringe in the interference pattern on the screen?

When you turn in your exam, show your I.D. card and sign the class list.
Directions: No books or notes may be used during this exam. Important formulas are provided for you.
Graphing calculators and palmtop or laptop computers are not allowed. Write everything on the exam booklet provided. Always include three significant digits in your numerical answers.

\[
\begin{align*}
\vec{F}_s &= -k\vec{x} \\
\vec{x}(t) &= A\cos(\omega t + \phi_0) = A\sin(\omega t) + b \cos(\omega t) \quad \omega = \sqrt{\frac{k}{m}} \\
U_s &= \frac{1}{2}kx^2 \quad \omega = 2\pi f \quad T = \frac{1}{f} \\
\sin \theta &= \tan \theta \equiv \theta \\
\omega &= \sqrt{\frac{g}{L}} \\
\vec{F}_D &= -b\vec{v} \\
\vec{x}(t) &= A \exp(-\beta t) \cos(\omega t) \quad \alpha = \frac{b}{2m} \\
v &= \lambda f = \frac{\omega}{k} \quad l = \frac{P}{a} \\
v &= (331 + 0.6T_C) \quad \beta = 10 \log_{10}\left(\frac{I}{I_0}\right) \quad I_0 = 1.00 \times 10^{-12} \text{ W/m}^2 \\
k &= \frac{2\pi}{\lambda} \quad \Delta r = m\lambda \\
\lambda_n &= \frac{2L}{m} \quad f_n = \frac{mv}{2L} \quad m \in \{1, 2, 3, ...\} \\
\lambda_m &= \frac{4L}{m} \quad f_m = \frac{mv}{4L} \quad m \in \{1, 3, 5, ...\} \\
d \sin \theta_n &= m\lambda \\
d \sin \theta_m &= (m + \frac{1}{2})\lambda \\
a \sin \theta_p &= p\lambda \\
a \sin \theta_p &= (p + \frac{1}{2})\lambda
\end{align*}
\]

Question 1: WRITE THE FORM DESIGNATOR FOR THIS EXAM (C) IN THE ANSWER BOX FOR QUESTION #1 ON THE FIRST PAGE OF THE EXAM BOOKLET.

Questions 2-6 (5 points each) Multiple Choice. You will be graded on your answer only. It is not necessary to show your work for these problems. Put the answer for each question in the proper numbered box on the first page of your test booklet.

2. What causes beats? (A) time-like interference of two waves with the same frequency (B) time-like interference of two waves with different frequencies (C) the Doppler effect when both the source and observer are moving (D) variations in the pressure of a medium due to changes in its density.

3. If the intensity of a wave doubles, then what happens to its intensity level? (A) It doubles also. (B) It increases by a factor of ten. (C) It increases by a factor of one hundred. (D) It increases by 1 decibel. (E) It increases by 2 decibels. (F) It increases by 3 decibels. (G) It increases by 10 decibels.

4. What is diffraction? (A) Waves spread out because they have different wavelengths. (B) Waves spread out after going through an opening in a barrier. (C) Waves combine to make larger or smaller waves.

5. In an active sonar experiment, the outgoing sound wave has a frequency of 48.0 kHz, the reflected sound wave has a frequency of 52.0 kHz, and the speed of sound in the medium carrying the sound wave is 400 m/s. With respect to the medium, how fast is the object moving off of which the sound wave reflected? (A) 4.00 m/s (B) 8.00 m/s (C) 16.0 m/s (D) 100 m/s (E) 400 m/s (F) 1600 m/s (G) There isn't enough information given to answer.

6. In the fundamental mode of oscillation of a wave on a guitar string, the wavelength is 1.20 m, the frequency is 250 Hz, and the speed of the wave is 300 m/s. What would be the wavelength of the fundamental mode if the speed was increased to 600 m/s? (A) 0.300 m (B) 0.600 m (C) 2.40 m (D) 4.80 m (E) 250 m (F) 600 m (G) None of the above.

TURN THE PAGE OVER
Solve the following three problems on the front of the next three pages of your exam booklet. Solve each problem on a separate page, in numerical order. For full credit, include the following:

1. Translate the problem statement from English into math. Write equations of the form "symbol equals number units". Include such equations for any constants used in the solution. Write "symbol equals ?" to indicate which quantity is to be determined.
2. Draw the physical representations (graph, diagram, free-body diagram, etc.). Include coordinate axis, if appropriate. Give each axis a label and indicate positive and negative directions, if appropriate.
3. Solve for the unknown quantity. For full credit, include the only mathematical representations which are used in the solution from the list of formulas on the other side of this exam.

7. (25 pts.) **Determining Mass**

A spring oscillates with a period of 2.00 s when a block of mass \( m \) is attached to it and the other end is attached to a large, immovable object. When the mass is increased by 2.00 kg, the period of oscillation is 3.00 s. Determine the mass \( m \). Assume that friction and air resistance are negligible and that the mass moves on a flat, horizontal surface.

8. (25 pts.) **Constructive Interference**

One speaker is located at \( (x, y) = (-1.00\ m, 0\ m) \) and the other is located at \( (x, y) = (0\ m, 3.00\ m) \). The speakers emit identical sound waves of wavelength 2.00 m which are initially in phase. Where on the positive \( x \)-axis does constructive interference occur? For full credit, follow the directions.

9. (25 pts.) **Diffraction Grating**

Light of a single wavelength passes perpendicularly through a diffraction grating. The first-order bright fringe in the interference pattern on a screen is at an angle of 11.3 degrees. The screen and diffraction grating are parallel to each other. At what angle is the fourth-order bright fringe in the interference pattern on the screen?

**WHEN YOU TURN IN YOUR EXAM, SHOW YOUR I.D. CARD AND SIGN THE CLASS LIST.**
Directions: No books or notes may be used during this exam. Important formulas are provided for you. Graphing calculators and palmtop or laptop computers are not allowed. Write everything on the exam booklet provided. Always include three significant digits in your numerical answers.

\[ F_s = -kv \]
\[ \ddot{x}(t) = A \cos(\omega t + \phi_s) = a \sin(\omega t) + b \cos(\omega t) \quad \omega = \sqrt{\frac{k}{m}} \quad U_s = \frac{1}{2} k x^2 \quad \omega = 2\pi f \quad T = \frac{1}{f} \]

\[ \sin \theta = \tan \theta \quad \omega = \sqrt{\frac{g}{L}} \quad \ddot{x}_D = -b \ddot{v} \quad \ddot{x}(t) = A e^{-\alpha t} \cos(\omega t) \quad \alpha = \frac{b}{2m} \quad \omega' = \sqrt{\frac{k}{m} - \frac{\beta^2}{4m^2}} \]

\[ v = \frac{\lambda f}{k} \quad I = \frac{P}{a} \quad v = (331 + 0.6 T_c) \quad \beta = 10 \log_{10} \left( \frac{I}{I_0} \right) \quad I_0 = 1.00 \times 10^{-12} W/m^2 \quad f = f_0 \left( \frac{v + v_o}{v} \right) \]

\[ k = \frac{2\pi}{\lambda} \quad \Delta r = m \lambda \quad \Delta r = (m + \frac{1}{2}) \lambda \quad m \in \{0, 1, 2, 3, ...\} \quad f_{beat} = |f_1 - f_2| \quad n = \frac{c}{v} \]

\[ \lambda_m = \frac{2L}{m} \quad f_m = \frac{mv}{2L} \quad m \in \{1, 2, 3, ...\} \quad \lambda_m = \frac{4L}{m} \quad f_m = \frac{mv}{4L} \quad m \in \{1, 3, 5, ...\} \]

\[ d \sin \theta_m = m \lambda \quad d \sin \theta_m = (m + \frac{1}{2}) \lambda \quad a \sin \theta_p = p \lambda \quad a \sin \theta_p = (p + \frac{1}{2}) \lambda \]

**Question 1:** WRITE THE FORM DESIGNATOR FOR THIS EXAM (D) IN THE ANSWER BOX FOR QUESTION #1 ON THE FIRST PAGE OF THE EXAM BOOKLET.

Questions 2-6 (5 points each) Multiple Choice. You will be graded on your answer only. It is not necessary to show your work for these problems. Put the answer for each question in the proper numbered box on the first page of your test booklet.

2. In the fundamental mode of oscillation of a wave on a guitar string, the wavelength is 1.20 m, the frequency is 250 Hz, and the speed of the wave is 300 m/s. What would be the wavelength of the fundamental mode if the speed was increased to 600 m/s? (A) 0.300 m (B) 0.600 m (C) 2.40 m (D) 4.80 m (E) 250 m (F) 600 m (G) None of the above.

3. What causes beats? (A) time-like interference of two waves with the same frequency (B) time-like interference of two waves with different frequencies (C) the Doppler effect when both the source and observer are moving (D) variations in the pressure of a medium due to changes in its density.

4. If the intensity of a wave doubles, then what happens to its intensity level? (A) It doubles also. (B) It increases by a factor of ten. (C) It increases by a factor of one hundred. (D) It increases by 1 decibel. (E) It increases by 2 decibels. (F) It increases by 3 decibels. (G) It increases by 10 decibels.

5. What is diffraction? (A) Waves spread out because they have different wavelengths. (B) Waves spread out after going through an opening in a barrier. (C) Waves combine to make larger or smaller waves.

6. In an active sonar experiment, the outgoing sound wave has a frequency of 48.0 kHz, the reflected sound wave has a frequency of 52.0 kHz, and the speed of sound in the medium carrying the sound wave is 400 m/s. With respect to the medium, how fast is the object moving off of which the sound wave reflected? (A) 4.00 m/s (B) 8.00 m/s (C) 16.0 m/s (D) 100 m/s (E) 400 m/s (F) 1600 m/s (G) There isn't enough information given to answer.

**TURN THE PAGE OVER**
Solve the following three problems on the front of the next three pages of your exam booklet. Solve each problem on a separate page, in numerical order. For full credit, include the following:

1. Translate the problem statement from English into math. Write equations of the form "symbol equals number units". Include such equations for any constants used in the solution. Write "symbol equals ?" to indicate which quantity is to be determined.
2. Draw the physical representations (graph, diagram, free-body diagram, etc.). Include coordinate axis, if appropriate. Give each axis a label and indicate positive and negative directions, if appropriate.
3. Solve for the unknown quantity. For full credit, include the only mathematical representations which are used in the solution from the list of formulas on the other side of this exam.

7. (25 pts.) Determining Mass

A spring oscillates with a period of 2.00 s when a block of mass \( m \) is attached to it and the other end is attached to a large, immovable object. When the mass is increased by 2.00 kg, the period of oscillation is 3.00 s. Determine the mass \( m \). Assume that friction and air resistance are negligible and that the mass moves on a flat, horizontal surface.

8. (25 pts.) Constructive Interference

One speaker is located at \( (x, y) = (-1.00 \text{ m}, 0 \text{ m}) \) and the other is located at \( (x, y) = (0 \text{ m}, 3.00 \text{ m}) \). The speakers emit identical sound waves of wavelength 2.00 m which are initially in phase. Where on the positive x-axis does constructive interference occur? For full credit, follow the directions.

9. (25 pts.) Diffraction Grating

Light of a single wavelength passes perpendicularly through a diffraction grating. The first-order bright fringe in the interference pattern on a screen is at an angle of 11.3 degrees. The screen and diffraction grating are parallel to each other. At what angle is the fourth-order bright fringe in the interference pattern on the screen?

**WHEN YOU TURN IN YOUR EXAM, SHOW YOUR I.D. CARD AND SIGN THE CLASS LIST.**