Instructions:
1. Please do not start the exam until instructed!

2. Print your Name and ID# and sign your NAME at the top of this page.

3. Calculators are allowed. No books or notes are allowed. Please leave your course materials at the rear of the room.

4. The exam consists of 5 Questions (8 points each or 40 points) and 5 Problems (12 points each or 60 points), for a total of 100 points. Please budget your time with these values in mind.

5. The last page contains Equations, Conversion Factors, and Constants. You may gently tear off this last page for use during the test.

6. If you have any questions or if you need extra paper, please raise your hand.

7. At the end of the exam please turn in your test paper at the front of the room.

8. Please keep your work covered and your eyes on your own paper during the exam. The penalty for cheating is an automatic zero.

9. Good luck!

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I. Questions: 40 points (Where indicated show work with units to receive credit.)

Q1. Sound refers either to an auditory sensation in the ear or to the disturbance in air that causes this sensation. Its waves are _______________ vibrations of air molecules that carry _______________ from one point in space to another. Sound waves passing through an aperture will spread out due to _______________.

Q2. The speed of a wave depends on: (select one answer)
   (a) mechanical properties of the medium in which it propagates
   (b) its wavelength
   (c) the amplitude of the disturbance being propagated
   (d) whether it is a wave pulse or a continuous wave

Q3. Steel has a density of about 7700 kg/m$^3$. What is it in units of g/cm$^3$?
   (Show your work to receive credit.) _______________

Q4. A sound wave passing through air produces the pressure variation $\Delta p$ with time $t$ (as measured at a particular point in space) that is illustrated below.

   ![Graph of sound wave]

   (a) The amplitude of the oscillation in micropascals = _______________.

   (b) The period of the oscillation in milliseconds = _______________.

   (c) The frequency of the oscillation in Hertz = _______________.

Q5. Under what condition(s) does resonance occur?
II. Problems: 60 points (Show your work to receive full credit. Answers must have units.)

P1. A 1.30 kg ball is thrown directly upward with an initial velocity of 19.6 m/s. It is acted upon by gravity – recall that the acceleration due to gravity near the earth’s surface is 9.81 m/s$^2$.
(a) What is the downward force acting on the ball due to gravity?
(b) What is the height that the ball will reach before it starts to fall? Ignore air resistance. [Hint: use conservation of mechanical energy.]
(c) When the ball returns to the point from which it was thrown, what is its velocity? Again ignore air resistance. [Hint: again use conservation of mechanical energy.]

P2. A stretched string of length 1.80 m, fixed at both ends, is vibrating in its 3rd normal mode (where the fundamental is the 1st mode). The total mass of the string is 0.00150 kg, and the frequency of oscillation in this mode is 720 Hz.
(a) Sketch the shape of the string at a time when it is at its maximum distortion.
(b) What is the wavelength of this standing wave?
(c) What is the tension of the string, in Newtons?
P3. It is well known that male zebra finches sing a very highly rehearsed song to attract females. The primary frequency of this song is at about 3,000 Hz. It is not known what criteria are used by the female birds to accept a particular male, but let’s suppose that they only accept males whose songs are at a frequency of less than 3.200 kHz. For this problem use $v = 343.1 \text{ m/s}$ for the speed of sound in air.

(a) Suppose a particular male zebra finch has perfect pitch and can sing songs with a primary frequency of 3.000 kHz exactly. If this bird is flying toward a stationary female with a velocity of 22.00 m/s while singing, will the female be attracted or not? Explain why or why not.

(b) What about for the case where the male bird in (a) is stationary, but the female bird is moving toward the male bird with a velocity of 22.00 m/s?

P4. An air-filled pipe open at both ends has a length of 1.50 m. The temperature is 20°C, so the speed of sound is 343 m/s.

(a) What is the frequency of the fundamental standing wave in this pipe?

(b) If one end of the pipe is closed, what is the new fundamental frequency?

(c) For this closed pipe, what is the frequency of the next highest resonant mode?
A block of mass $m = 0.42 \, kg$ is resting on a frictionless surface, and is attached to a fixed wall by a spring with spring constant $k = 250 \, N/m$. A person displaces the block from its equilibrium position by a distance $x = 5.0 \, cm$, and then releases it.

(a) What is the frequency (in Hz) of the ensuing simple harmonic motion of the block?

(b) How much time elapses from when the block is released to when it passes through its equilibrium position? [Hint: use your result from part (a).]

(c) What is the amplitude of the oscillation?

(d) What is the total mechanical energy (in Joules) of the system as it is oscillating?
Equations

Motion: speed \( v = \frac{\Delta x}{\Delta t} \); for motion with constant speed \( v \), the distance \( d = vt \).

acceleration \( a = \frac{\Delta v}{\Delta t} \); for motion with constant \( a \), \( v = at \) and \( d = \frac{1}{2}at^2 \).

Newton’s 2nd Law: \( F_{\text{net}} = ma \); Weight: \( w = mg \); Force due to spring: \( F_{\text{spr}} = -kx \).

Energy: kinetic energy \( KE = \frac{1}{2}mv^2 \); potential energy \( PE_{\text{grav}} = mgh \) & \( PE_{\text{spr}} = \frac{1}{2}kx^2 \).

Work and Energy: Work = Force \( \times \) distance; \( W = Fd \); Work done = \( \Delta KE \).

Conservation of energy: \( KE + PE = \text{constant} = E_{\text{total}} = \frac{1}{2}m(v_{\text{bot}})^2 = mgh_{\text{top}} \).

Periodic motion: frequency \( f \) (Hz); period \( T \) (s); \( f = \frac{1}{T} \); amplitude \( A \); \( PE_{\text{max}} = \frac{1}{2}kA^2 \).

Mass on spring: \( F_{\text{sp}} = -ky \), \( f = \pi \sqrt{\frac{k}{m}} \); Pendulum: \( f = \frac{1}{2}\pi \sqrt{\frac{g}{l}} \).

Relations involving \( v \), the wave speed:
- wave relation: \( v = \lambda f \)
- sound wave in air: \( v = (331.3 + 0.6 t_{\circ C}) \) m/s → at 20°C \( v = 343.3 \) m/s
- wave on a string: \( v = \sqrt{T/\mu} \), \( T \) is string tension \([N]\) and \( \mu \) is mass/length \([kg/m]\).

Wave propagation: reflection \( (\theta_{\text{inc}} = \theta_{\text{refl}}) \); refraction (speed varies); diffraction (size~\( \lambda \)).

Wave interference due to path length difference, \( (d_2 - d_1) \):
- constructive, \( (d_2 - d_1) = 0, \lambda, 2\lambda, 3\lambda \ldots \)
- destructive, \( (d_2 - d_1) = 1/2\lambda, 3/2\lambda, 5/2\lambda \ldots \)

Doppler effect: receiver(R) moving & source(S) stationary: \( f_R = f_S(v + v_R)/v \)
receiver(R) stationary & source(S) moving: \( f_R = f_S v/(v - v_S) \).

Interference of waves with \( f_1 = f_2 \): \( f_{\text{perceived}} = \frac{1}{2}(f_1 + f_2) \); \( f_{\text{beats}} = f_2 - f_1 \).

Harmonic Series for Standing waves: harmonic number \( n \), fundamental is \( n = 1 \).

On a string: \( f_n = n f_1 \), \( \lambda_n = 2L/n \), for \( n = 1,2,3\ldots \) \( f_n = v/\lambda_n = (n/2L)\sqrt{T/\mu} \).

Open air-filled pipe: \( f_n = v/\lambda_n = (n/2L)v \), for \( n = 1,2,3\ldots \).

Closed air-filled pipe: \( f_n = v/\lambda_n = (n/4L)v \), for \( n = 1,3,5\ldots \).

### Conversion Factors and Constants

<table>
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<tr>
<th>Conversion Factors</th>
<th>Constants</th>
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<tr>
<td>1 kg = 1000 gm</td>
<td>Acceleration due to gravity ( g = 9.8 ) m/s(^2)</td>
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<td>1 m = 100 cm = 39.37 in</td>
<td>Density ((\rho = \text{Mass/Volume})) ( \text{Water} = 1000 ) kg/m(^3)</td>
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<tr>
<td>1 km = 1000 m</td>
<td>( \text{Steel} = 7700 ) kg/m(^3)</td>
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<td>1 in = 2.54 cm</td>
<td>( 1 ) s = 1000 ms</td>
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<td>1 ft = 12 in = 0.305 m</td>
<td>( 1 ) N = 1 kg(\times)m/s(^2)</td>
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<tr>
<td>1 mile = 5280 ft = 1610 m</td>
<td>( 1 ) J = 1 N(\times)m = 1 kg(\times)m(^2)/s(^2)</td>
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<tr>
<td>1 hour = 3600 s</td>
<td>Abbreviations</td>
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<tr>
<td>( 1 ) N = 1 kg(\times)m/s(^2)</td>
<td>mega ( M = 10^6 )</td>
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<td>( 1 ) J = 1 N(\times)m = 1 kg(\times)m(^2)/s(^2)</td>
<td>kilo ( k = 10^3 )</td>
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<td>milli ( m = 10^{-3} )</td>
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<td>micro ( \mu = 10^{-6} )</td>
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