Name:____________________________________

Student ID #:________________________________

Signature:__________________________________

October 29, 2021

Physics 1B Midterm #2, version A

- You have 50 minutes to complete this exam. You MUST close the exam and hand it in at the front when time is up. <u>Show your student ID when handing in your exam. If we have to come collect your exam from your row, your exam will be marked so that 25% will be immediately deducted.</u>

- Numerical values in answers: quote values with 3 significant figures, for example, 1.32 or 9.72. Always specify the units, even for intermediate results, and quote your final answer in SI units unless indicated otherwise.

- Exam rules:

    - The last sheet of the exam is an equation sheet that may be torn off. Do not write on the equation sheet. If you need extra paper, use the back of each sheet or the extra sheet of scratch paper provided just before the equation sheet.
    - You can use any type of calculator that does not have internet capability. Put away your cell phones and laptops.
    - Questions during the exam – you may raise your hand if you are seated near the end of a row, otherwise, unfortunately, you may need to come down to the front to ask.

- You MUST sign and date the 2^{nd} page entitled "Academic Integrity – A Bruin's Code of Conduct" in order to receive credit for your work.

- Remember to write down each step of your calculation, and explain your answers fully.

Score :

I.	(Mult choice)	__________/10 points
II.		__________/10 points
III.		__________/10 points
IV.		__________/10 points
	Total	__________/40 points

I) Multiple Choice - circle the *one* correct answer to each question.

1. A crystal wine glass can be broken by sound of a particular frequency. This is an example of:

   a. Damped oscillation
   b. Conservation of energy
   c. Resonance
   d. Pendulum motion

2. A mass is oscillating on a spring (with no friction). At the instant in time when the mass is at its equilibrium point, the total energy of the mass-spring system is:

   a. Zero
   b. All in the form of potential energy
   c. All in the form of kinetic energy
   d. Given by the formula $\frac{1}{2}kx^2$
   e. Larger than at any other point in the motion

$E = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$

$\therefore x = 0 \Rightarrow E = \frac{1}{2}mv^2$

3. If the maximum pressure of a sound wave increases by a factor of 2, approximately how much is the intensity increased in decibels?

   a. 2 db
   b. 3 db
   c. 4 db
   d. 6 db
   e. 10 db
   f. 20 db

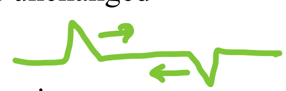
$I = \frac{P_{max}^2}{2\rho v}$

$I / I_0 = \left(\frac{P_{max}'}{P_{max}}\right)^2 = 2^2 = 4$

$\beta = 10\ dB \cdot \log_{10}(4) = 6\ dB$

4. Two short pulses are travelling down a long stretched string in opposite directions. The first pulse, coming from the left, is a positive (+y) triangular-shaped pulse, and the second pulse, coming from the right, is also triangular of the same shape but negative (-y) displacement. The two pulses:

   a. Add up to zero momentarily when they meet but pass through each other unchanged
   b. Reverse direction (bounce off each other) when they meet
   c. Add up to zero when they meet and then disappear
   d. Add up to twice the displacement and then make a standing wave on the string



5. Guitar players Stella and Sam are playing in unison. Stella's A-string is tuned to 445 Hz while Sam's A-string is tuned to 443 Hz. When both are playing A notes with the same intensity, the audience hears:

   a. A steady sound of frequency 888 Hz.
   b. A steady sound of frequency 2 Hz.
   c. Sound of frequency 444 Hz with a periodic 2Hz variation in volume.
   d. Both 443 Hz and 445 Hz notes are heard.

$f_{beats} = |f_a - f_b|$

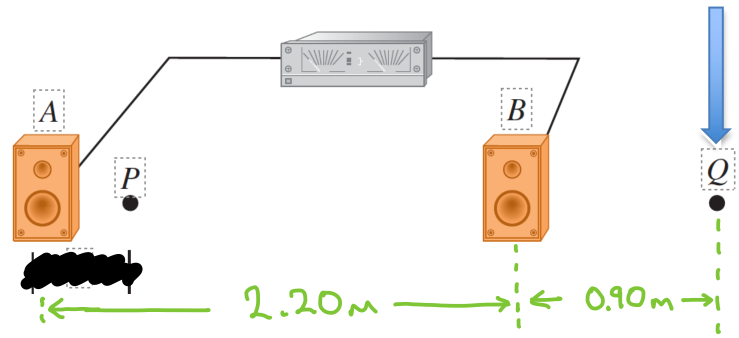
II (10 points): Two loudspeakers, *A* and *B* (see the figure below), are driven by the same amplifier and emit sinusoidal waves in phase. Speaker *B* is 2.20 m to the right of speaker *A*. Consider a point *Q* along the extension of the line connecting the speakers, 0.90 m to the right of speaker *B*. Both speakers emit sound waves that travel directly from the speaker to point *Q*. Take the speed of sound to be 340 m/s.

a) (4 pts) What is the lowest frequency for which constructive interference occurs at point *Q*?
b) (3 pts) What is the lowest frequency for which destructive interference occurs at point *Q*?
c) (3 pts) What higher frequencies will have destructive interference occurring at point *Q*?

$d_A = 2.20 + 0.90\,m$

$d_A = 3.10\,m$ dist. from A

$d_B = 0.90\,m$ dist. from B



Constructive interference when $|d_A - d_B| = n \cdot \lambda$, integer wavelengths

$$\lambda = \frac{1}{n}|d_A - d_B| = \frac{1}{n}\cdot 2.20\,m$$

Destructive when $|d_A - d_B| = (n+\frac{1}{2})\lambda$, half-integer wavelengths

$$\lambda = \frac{1}{n+1/2}|d_A - d_B| = \frac{1}{n+1/2}\cdot 2.20\,m$$

We get frequencies from $f = \frac{v}{\lambda}$:

a) $$f = \frac{v}{1/n\,|d_A - d_B|} = n\cdot\frac{v}{|d_A - d_B|} = n\cdot\frac{340\,m/s}{2.20\,m}$$

$f = n \cdot 154.5\,Hz$, the lowest is $n=1$ where $\boxed{f = 154.5\,Hz}$

b) $$f = \frac{v}{1/(n+1/2)\,|d_A - d_B|} = \frac{(n+1/2)\,v}{|d_A - d_B|}$$

$^* f = (n+\frac{1}{2})\cdot 154.5\,Hz$, the lowest is $n=0$ where $\boxed{f = 77.2\,Hz}$

c) Algebraically, the equation * above, or $\boxed{f_n = 77.2 + n\cdot 154.5\,Hz}$, or give a few frequencies: $\boxed{f = 232, 386, 541\,Hz, \ldots}$

III (10 points): The mass of the only fish on the "30 biggest fish ever caught" list that comes from close to California is 193.7 kg (see below). If that fish were hung from an ideal spring having negligible mass, and as a result the fish stretched the spring 0.200 m:

a) (3 pts) Find the force constant k of the spring.
b) (3 pts) The fish is now pulled down an additional 5.00 cm and released. What is the period of oscillation T of the fish?
c) (4 pts) What is the maximum speed v_{max} the fish will reach in oscillation?

a) $F = mg = kx$

$$k = \frac{mg}{x} = \frac{193.7\,kg \cdot 9.8\,m/s^2}{0.200\,m} = \boxed{9.49 \times 10^3\,N/m}$$

b) $T = \frac{1}{f} = \frac{1}{\omega/2\pi} = \frac{2\pi}{\omega}$ and $\omega = \sqrt{k/m}$

so $$T = \frac{2\pi}{\sqrt{k/m}} = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{193.7\,kg}{9.49 \times 10^3\,N/m}}$$

$$\boxed{T = 0.90\,s}$$

c) $x = A\cos(\omega t)$

$v = \frac{dx}{dt} = -A\omega\sin(\omega t)$ maximum is

$V_{max} = A\omega$ (when $\sin(\omega t) = 1$)

$$V_{max} = A \cdot \frac{2\pi}{T} = 5.00 \times 10^{-2}\,m \cdot \frac{2\pi}{0.90\,s} = \boxed{0.35\,m/s}$$

IV (10 points) A sinusoidal transverse wave on a string has wave speed $v = 10.0\ m/s$, amplitude $A = 0.010\ m$, and wavelength $\lambda = 0.5\ m$. The wave travels in the $-x$ direction, and at $t = 0$ and $x = 0$ the string has its maximum upward displacement.

a) (2 pts) Find the frequency f of the wave.
b) (2 pts) Find the period T of the wave.
c) (2 pts) Find the wave number k of this wave.
d) (2 pts) Write a wave function $y(x,t)$ describing the wave, plugging in and simplifying all known numbers.
e) (2 pts) Find the transverse displacement of a particle at $x = 0.1\ m$ at time $t = 0.03\ s$.

a) $f = \frac{v}{\lambda} = \frac{10.0\ m/s}{0.5\ m} = \boxed{20\ Hz}$

b) $T = \frac{1}{f} = \boxed{5.0 \times 10^{-2}\ s}$

c) $k = \frac{2\pi}{\lambda} = \boxed{12.6\ /m}$

+ sign: travels toward $-x$

d) Use $y(x,t) = A\cos(kx + \omega t)$ which does have maximum displacement at $t = 0$ and $x = 0$ since $\cos(0 - 0) = \cos(0) = 1$. So we don't need a phase constant. $\omega = 2\pi f = 126\ /s$ is needed.

Plugging in:

$$\boxed{y(x,t) = 0.010\ m \cdot \cos(12.6/m \cdot x + 126/s \cdot t)}$$

e) $y(0.1\ m, 0.03\ s) = 0.010\ m \cdot \underbrace{\cos(\underbrace{1.26 + 3.78}_{5.04})}_{0.32}$

$$\boxed{y = 3.2 \times 10^{-3}\ m}$$

USED = *

Equation sheet (cumulative MT1 + MT2):

Possibly useful constants:

$g = 9.8\ {}^{m}/_{s^2}$ on Earth

$p_{atm} = 1.01 \cdot 10^5\ N/m^2$

$\rho(water) = 1000\ kg/m^3$

$\rho(air) = 1.30\ kg/m^3$ near sea level

$M = 28.8 \cdot 10^{-3}\ kg/mol$ for air

$R = 8.314\ J/mol \cdot K$

$v = 340\ m/s$ for sound in air at 290 K

Possibly useful equations:

$$Y = \frac{Tensile\ stress}{Tensile\ strain} = \frac{F_\perp/A}{\Delta l/l_0}$$

$$B = \frac{Bulk\ stress}{Bulk\ strain} = \frac{\Delta p}{\Delta V/V_0}$$

$$Shear\ stress = F_\parallel/A$$

$$\rho = {}^{m}/_{V}$$

$$p = \frac{dF_\perp}{dA}$$

$$p_2 - p_1 = -\rho g(y_2 - y_1)$$

$$p = p_0 + \rho g h$$

$$dV/_{dt} = A_1 v_1 = A_2 v_2$$

$$dm/_{dt} = \rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

$$p + \rho g y + \frac{1}{2}\rho v^2 = constant$$

$$f = {}^{1}/_{T} = {}^{\omega}/_{2\pi}$$

$$x = A\cos(\omega t + \phi)$$

$$\omega = \sqrt{{}^{k}/_{m}} \text{ or } \omega = \sqrt{{}^{g}/_{l}} \text{ or } \omega = \sqrt{\frac{mgd}{I}}$$

$$E = \frac{1}{2}kA^2$$

$$x = C_1 e^{-a_1 t} + C_2 e^{-a_2 t}$$

$$\frac{dE}{dt} = -bv^2$$

$$y(x,t) = f(x - vt) \text{ or } y(x,t) = f(x + vt)$$

$$y = A\cos(kx - \omega t) = A\cos\left(\frac{2\pi}{\lambda}x - 2\pi f t\right)$$

$$\lambda = \frac{2\pi}{k} \text{ and } f\lambda = v$$

$$v = \sqrt{\frac{Tension}{\mu}},\ \mu = \frac{m}{l},\ P_{av} = \frac{1}{2}\sqrt{\mu F}\,\omega^2 A^2$$

$$y = 2A\sin(kx)\sin(\omega t)$$

$$f_n = n\left(\frac{v}{2L}\right)$$

$$p(x,t) = B \cdot \frac{\Delta V}{V} = B\frac{\partial y(x,t)}{\partial x}$$

$$p_{max} = BkA$$

$$v = \sqrt{\frac{B}{\rho}} \text{ fluids or } v = \sqrt{\frac{Y}{\rho}} \text{ solids}$$

$$B = \gamma p_0 \text{ and } v = \sqrt{\frac{\gamma RT}{M}} \text{ gases}$$

$$\beta = (10\ db) \cdot \log_{10}\left(\frac{I}{I_0}\right),\ I_0 = 10^{-12} W/m^2$$

$$I = \frac{1}{2}B\omega k A^2 = \frac{1}{2}\sqrt{\rho B}\,\omega^2 A^2 = \frac{p_{max}^2}{2\rho v}$$

$$f_n = n \cdot \frac{v}{2L}, n = 1,2,3 \ldots \text{ or } f_n = n \cdot \frac{v}{4L}, n = 1,3,5, \ldots$$

$$f_{beats} = |f_a - f_b|$$

$$f_L = \left(\frac{v + v_L}{v + v_s}\right) f_s$$