# 20W-PHYSICS1B-2 Midterm 1

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TOTAL POINTS

**83 / 95**

QUESTION 1

## Concept questions 15 pts

**1.1 5 / 5**

**1.2 5 / 5**

**1.3 5 / 5**

QUESTION 2

## Problem 2 30 pts

**2.1 7 / 10**

**2.2 8 / 10**

**2.3 10 / 10**

QUESTION 3

## Problem 3 20 pts

3.1 Part A **10 / 10**

3.2 Part B **10 / 10**

QUESTION 4

## Problem 4 20 pts

4.1 Part A **10 / 10**

4.2 Part B **10 / 10**

QUESTION 5

5 Problem 5 **3 / 10**

**+ 1 Point adjustment**

Write your name here:

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Write your UCLA ID here

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# Midterm 1, Physics 1B, Version B

- Please write your name and UID in the boxes on the front page and your name in the boxes at the top of the odd numbered pages.
- Closed book, **one** 5x3in note card (both sides) allowed.
- Scientific Calculators allowed, no computers or smartphones, please put books and notebooks in your backpacks.
- If a problem is ambiguous, notify the instructor. Clarifications will be written on the blackboard. Check the board occasionally.
- Time for exam: 60 minutes
- There are 5 questions, check that your exam has all 12 pages.

Good Luck !!

-additional space for calculation-

Write your name here:

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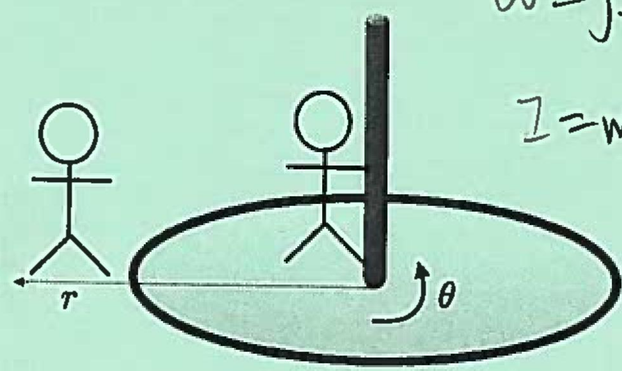
**Problem 1: [15pts] Concept questions**

**a) [5pts]** An children's playground toy can be viewed as a torsion pendulum undergoing simple harmonic oscillator motion. The angular displacement can be described by

$$\theta(t) = A\cos(\frac{2\pi}{T}t) \tag{1}$$

At time $t = T/2$ another child quickly jumps onto the toy (moving radially), what happens to the amplitude and the period of the oscillation ?




$\omega = \sqrt{\frac{K}{I}}$

$I = mr^2$, period

inertia ↑, so period

ω ↓, period ↑

K =

Circle the correct answer

A The period is unchanged and the the amplitude is unchanged

B The period is increases and the amplitude is unchanged.

C The period increases and the amplitude increases

D The period is unchanged and the the amplitude decreases

E The period decreases and the amplitude decreases

F The period is decreases and the amplitude is unchanged.

G The period decreases and the amplitude increases

**b)** [**5pts**] Consider the statement that energy is transported in a standing wave
Circle the correct answer

**A** is incorrect, since energy transported to the right and left cancel each other out

**B** is correct, since the standing wave is a superposition of left and right moving waves

**C** energy will be transported in a longitudinal standing wave, not a transverse one

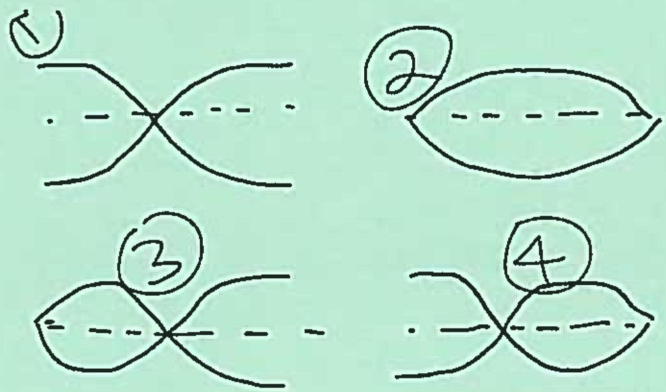
**D** the answer depends on whether we have fixed ends or free ends.

**E** is correct, since there is work done when the string is displaced.

**F** energy will be transported in a transverse standing wave, not a longitudinal one

Write your name here:

**c)** **[5pts]** Which of the following could describe the pressure amplitude in an organ pipe that is open on both ends ?




Circle the correct answer

**A** 2 only

**B** 3 only

**C** 4 only

**D** 1 only

**E** None of them since they are not the fundamental standing wave

**F** Both 3 and 4

**Problem 2:** [30pts] A string is made out of steel with density $\rho = 7.85g/cm^3$ and has a diameter of $d = 0.4mm$. One end is located at $x = 0$ and the other end is located at $x = L$, with $L = 6.00m$. At the end of the string located at $x = 0$, an external apparatus acts on the end, starting at time $t = 0$. The transverse displacement at $x = 0$ as a function of time is given by

$$y(t) = Asin(\omega t) \tag{2}$$

Where $A = 3.00mm$ and $\omega = 10^3 \frac{rad}{s}$. For times $t > 0$, a traveling wave is produced (neglect any effect of reflected waves for this problem)

**a)** [10pts] If the string is held under tension $T = 60.00N$ what is the wave speed and the wavelength of the traveling wave ?

$\mu = \frac{kg}{m}$ $\rho = \frac{7.85\ g}{cm^3}$ $\mu = \frac{7.85g}{cm^3} \cdot \left(\frac{100\ cm}{1m}\right)^3 \cdot \frac{1kg}{1000g} \cdot 7.54\times10^{-7}m^2 = 0.00592\ kg/m$

area $= \left(0.2mm \times \frac{1m}{1000mm}\right)^2 \pi = 1.26\times10^{-7}m \cdot 6.00\ m = 7.54\times10^{-7}m^2$

$v = \sqrt{\frac{60.00N}{0.00592 kg/m}} \approx \boxed{101\ m/s}$ $v = f\lambda$ $\lambda = \frac{v}{f}$ $f = \frac{\omega}{2\pi}$

$\lambda = \frac{2\pi v}{\omega} = \frac{2\pi(101\ m/s)}{10^3\ rad/s} = \boxed{0.633\ m}$

**b)** [10pts] Write down an expression $y(x, t)$ for the displacement of traveling wave

$y = f(x - vt)$

$y(x,t) = f(x - 101m/s\ t)$

$y(x,t) = A\cos\left(\frac{2\pi}{0.633m}(x - 101m/s\ t) + \phi_0\right)$

$\boxed{y(x,t) = -3.00mm\ \sin\left(\frac{2\pi}{0.633m}(x - 101m/s\ t)\right)}$

@ $x = 0$; $y = A\cos(-\omega t + \phi_0)$

$\cos(-30°) = \sin(30°)$

$\sin\theta = \cos(90 - \theta)$

$\sin(\omega t) = \cos(-\omega t + \Phi_0)$

$\sin(\omega t) = \cos(90 - -\omega t)$

$\cos(90 + \omega t)$

$\sin(-30°) = -\sin(30°)$

Write your name here:

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**c)** **[10pts]** Find the time $t$ at which the displacement of the string at $x = L/2$ is $-A$ for the first time [If you could not do a) assume $v = 175m/s$].

$v = 101\,m/s \quad y(x,t) = 3.00\,mm \cos\left(\frac{2\pi}{0.633m}(x + 101\,m/s \cdot t) + \frac{\pi}{2}\right)$

$y(x,t) = 3.00 \cos(29.78 + 1002.53t + \frac{\pi}{2})$

$y(x,t) = -3.00\,mm \sin\left(\frac{2\pi}{0.633m}(x - 101\,m/s \cdot t)\right)$

$-3.00\,mm \sin(29.78 - 1002.53t)$

$\sin(29.78 - 1002.53t) = 1$

$t = 0.0297\,s$

**Problem 3:** [20pts] You place a speaker connected to a sine wave generator close to one end of an organ pipe of unknown length $L$. You slowly increase the frequency of the sine wave generator from zero and for the frequencies $f_a = 85Hz$ and $f_b = 255Hz$ you find a resonant standing wave (but at no other frequency up to $f_b$). Assume that the speed of sound in air is $v = 340\frac{m}{s}$.

**a)** [10pts] Does the pipe have two open ends or one open and closed end (Justify your reasoning) ? Find the length of the pipe.

$\frac{f_b}{f_a} = \frac{255 Hz}{85 Hz} = 3 \quad f_a = f_1 \quad f_b = f_3$

the pipe has one open and one closed end, since it jumps $f_1$ to $f_3$, skipping $f_2$ - one open and one closed pipes have n values of 1, 3, 5, ... .

$f_1 = \frac{v}{4L} \qquad 85 Hz = \frac{340 m/s}{4(L)}$

$L = \frac{85 Hz \cdot 4}{340 m/s} = \boxed{1m}$

Write your name here:

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**b)** [10pts] You close all ends of the pipe and fill it with an unknown gas. You scan through the frequencies of the sine wave generator and there is a resonance. at $f_a = 450Hz$ and $f_b = 525Hz$ without any other resonances in between $f_a$ and $f_b$. What is the speed of sound in the gas ? [If you could not do a) assume $L = 1.20m$].

$f_b = 525\ Hz \quad f_a = 450\ Hz$

$\frac{f_b}{f_a} = \frac{525\ Hz}{450\ Hz} = \frac{7}{6} \quad f_6 = \frac{6 \cdot V_{sound}}{2 \cdot L}$

$450\ Hz = \frac{6 \cdot V_{sound}}{2 \cdot 1m}$

$V_{sound} = \frac{450\ Hz \cdot 2m}{6} = \boxed{150\ m/s}$

**Problem 4:** [20pts] A mass $m = 3.00kg$ is connected to an ideal spring with spring constant $k = 11.00N/m$. Neglect any friction in this problem.

The equilibrium of the spring is at $x = 0$. At $t = 0$ you compress the spring so that $x = -0.10m$ and give it a push so that the initial velocity is $v = -1.70m/s$. We describe the ensuing simple harmonic oscillations by

$$x(t) = A\,cos(\omega t + \phi_0), \qquad -\pi < \phi_0 \leq +\pi \tag{3}$$

**a)** [10pts] Find $\omega$, $A$ and $\phi_0$.

$w = \sqrt{\frac{k}{m}} = \sqrt{\frac{11.00\ N/m}{3.00\ kg}} = \boxed{1.91\ rad/s} \leftarrow w$

$x = A\cos(wt + \phi_0)$ $\quad x(0) = A\cos(\phi_0) = -0.10$

$v = -Aw\sin(wt + \phi_0)$ $\quad v(0) = -A(1.91\ rad/s)\sin(\phi_0) = -1.70\ m/s$

$A\sin\phi_0 = 0.89\ m\ rad$

$A\cos\phi_0 = -0.10\ m\ rad$

$\tan\phi_0 = -8.88$

$\phi_0 = -1.46\ rad + \pi = \boxed{1.68\ rad} \leftarrow \phi_0$

$x(0) = -0.10 = A\cos(1.68\ rad)$

$A = \frac{-0.10}{\cos(1.68\ rad)}$

$\boxed{A = 0.89\ m}$

**b)** [10pts] At what time $t > 0$ does the mass reach the largest positive displacement for the first time ? [If you could not do a) assume $\phi_0 = 1.80$ rad]

CHALAH

$x = 0.89m\cos(1.91\ rad/s\ t + 1.68\ rad)$

$\cos(1.91\ rad/s\ t + 1.68\ rad) = 1$

$1.91\ rad/s \cdot t + 1.68\ rad = 2\pi$

$\boxed{t = 2.41\ s}$

Write your name here:

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**Problem 5)** [10pts] Consider a mass $M$ connected to a a spring which has the following potential energy function (no other forces are present)

$$U(x) = \frac{1}{3}\alpha(\sqrt{1+\frac{x^2}{x_0^2}} - 1) \tag{4}$$

Find the location of stable equilibrium and calculate the period of small oscillations of a mass $M$ around the equilibrium in terms of $M, \alpha$ and $x_0$.

$$U(x) = \frac{1}{3}\alpha\left(\sqrt{1+\frac{x^2}{x_0^2}} - 1\right)$$

$$\frac{1}{2}kx^2 = \frac{1}{3}\alpha\left(\sqrt{1+\frac{x^2}{x_0^2}} - 1\right)$$

~~$U'(x) = 0$~~; $U(x) = 0$, $\frac{1}{3}\alpha\sqrt{1+\frac{x^2}{x_0^2}} - \frac{1}{3}\alpha = 0$

$x = 0$ : stable equilibrium

small oscillation period:

$$\omega = \sqrt{\frac{k}{m}} \qquad k = \frac{2\alpha}{3x^2}\left(\sqrt{1+\frac{x^2}{x_0^2}} - 1\right)$$

$$2\pi f = \omega \qquad T = \frac{2\pi}{\omega}$$

$$T = 2\pi\sqrt{\frac{M}{\frac{2\alpha}{3x^2}\left(\sqrt{1+\frac{x^2}{x_0^2}} - 1\right)}}$$

-additional space for calculation-