20W-PHYSICS1B-2 Midterm 1

ALEXANDER SWERDLOW

TOTAL POINTS

89 / 95

QUESTION 1

Concept questions 15 pts

1.1 5 / 5

1.2 0 / 5

1.3 5 / 5

QUESTION 2

Problem 2 30 pts

2.1 10 / 10

2.2 10 / 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 **9 / 10**

+ 1 Point adjustment

Write your name here:

Alexander Swerdlow

Write your UCLA ID here

305065891

Midterm 1, Physics 1B, Version A

- 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:

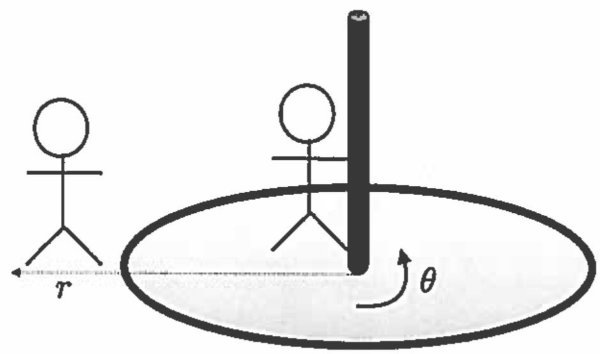
Problem 1: [15pts] Concept questions

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

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

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 ?

ω



Circle the correct answer

~~A~~ The period decreases and the amplitude increases

~~B~~ The period decreases and the amplitude decreases

C The period increases and the amplitude increases

~~D~~ The period is unchanged and the the amplitude decreases

E The period is increases and the amplitude is unchanged.

~~F~~ The period is decreases and the amplitude is unchanged.

~~G~~ The period is unchanged and the the amplitude is unchanged

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

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

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

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

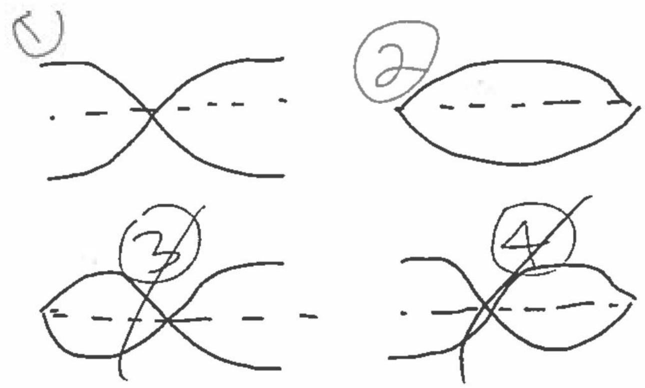
D energy will be transported in a longitudinal standing wave, not a transverse one

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

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

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 4 only

B 2 only

C 1 only

D 3 only

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

F Both 3 and 4

4 kg		40009
2 m^3		100
1	100·100·100

Problem 2: [30pts] A string is made out of steel with density $\rho = 7.85g/cm^3$ and has a diameter of $d = 0.5mm$. One end is located at $x = 0$ and the other end is located at $x = L$, with $L = 5.00m$. 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 $A = 2.00mm$ 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 $T = 50.00N$ what is the wave speed and the wavelength of the traveling wave ?

$V = \sqrt{\frac{Tension}{\mu}}$ $\mu = Area \cdot density = \left(\frac{0.5E\text{-}3\ m}{2}\right)^2 \pi \cdot density$

$\mu = 1.9635E\text{-}7 m^2 \cdot 7850 \frac{kg}{m^3}$

$V = \sqrt{\frac{50\ N}{1.5413E\text{-}7 \frac{kg}{m}}}$ $= 0.001541 \frac{kg}{m}$

$\boxed{V = 180.104 m/s}$ $V = f\lambda$ $\lambda = \frac{V}{f}$ $\lambda = \frac{V}{\left(\frac{\omega}{2\pi}\right)} = \frac{2\pi V}{\omega}$

$= \frac{2\pi \cdot 180.10}{10^3 rad/s}$

$\boxed{\lambda = 1.132 m}$

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

$y(x,t) = 2\times10^{-3} m \cos\left(\frac{2\pi}{1.131m} x - 10^3 \frac{rad}{s} t + \pi/2\right)$

Write your name here:

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 $v = 170m/s$].

$L = 5m \qquad L/2 = 2.5m$

$$y(x,t) = 2E{-}3m \cos\left(\frac{2\pi}{1.131m} x - 10^3 \cdot t + \pi/2\right)$$

$$-2E{-}3m = 2E{-}3m \cos\left(\frac{2\pi}{1.131m} \cdot 2.5m - 10^3 \cdot t + \pi/2\right)$$

$$-1 = \cos\left(\frac{2\pi}{1.13m} \cdot 2.5m - 10^3 t + \pi/2\right)$$

$\boxed{t = 0.006034 \text{ sec}}$

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 $f_a = 75Hz$ and $f_b = 225Hz$ you find a resonant standing wave (but at no other frequency up to f_b). Assume that the speed of sound in air is $v = 340\frac{m}{s}$.

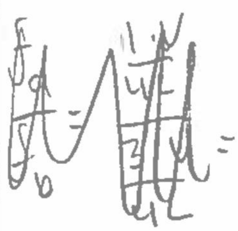
a) **[10pts]** Does the pipe have two open ends or one open and closed end (Justify your reasoning) ? Find the length of the pipe.

$n=1$ $f_a = 75hz$

$n=3$ $f_b = 225hz$

and V is const

The pipe must have one end open and one end closed as $f_b = 3f_a$ So $n=3$ and we know that f_a is the first harmonic (fundamental freq.). and f_b is the second. We can use the formula $f_n = \frac{nV}{4L}$ to show this correlation whereas this would not work if the pipe had two open/closed ends as n would be 2 and we would use $f_n = \frac{nV}{2L}$



$f_a = \frac{1 \cdot V}{4L}$

$75hz = \frac{340 m/s}{4 \cdot L}$

$300 \cdot L = 340$

$L = 1.13m$

Write your name here:

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 $f_a = 510Hz$ and $f_b = 595Hz$ 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 $L = 1.20m$].

$L = 1.13m$

$$595 - 510 = \frac{1 \cdot v}{2 \cdot L} = \frac{v}{2 \cdot 1.13}$$

$$85 = \frac{v}{2 \cdot 1.13}$$

$$\boxed{v = 192.1\ m/s}$$

Problem 4: [20pts] A mass $m = 3.20kg$ is connected to an ideal spring with spring constant $k = 10.00N/m$. Neglect any friction in this problem.

The equilibrium of the spring is at $x = 0$. At $t = 0$ you compress the spring so that $x = -0.20m$ and give it a push so that the initial velocity is $v = -2.70m/s$. 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 ω, A and ϕ_0.

$\phi_0 = \tan^{-1}\left(\frac{-V_0}{\omega X_0}\right) = \tan^{-1}\left(\frac{-(-2.70m/s)}{\left(\sqrt{\frac{10}{3.2}}\right)\cdot(-0.20)}\right) + \pi = -1.44 + \pi$ rads

$\boxed{\phi_0 = 1.701 \text{ rads}}$

$E_T = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}\cdot 3.2kg\cdot(-2.7m/s)^2 + \frac{1}{2}10\frac{N}{m}\cdot(-0.2m)^2$

$= 11.864J$

$\frac{1}{2}kA^2 = 11.864J$

$A^2 = \frac{11.864\cdot 2}{k}$

$\boxed{A = 1.54m}$

$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{10\frac{N}{m}}{3.2kg}} = \boxed{1.76 \text{ rads}}$

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 $\phi_0 = 1.60$ rad]

$x(t) = A\cos(\omega t + \phi_0)$

$1.54^m = 1.54^m\cos(1.76t + 1.701)$

$1 = \cos(1.76t + 1.701) \Rightarrow \boxed{t = 2.604 \text{ Sec}}$

Write your name here:

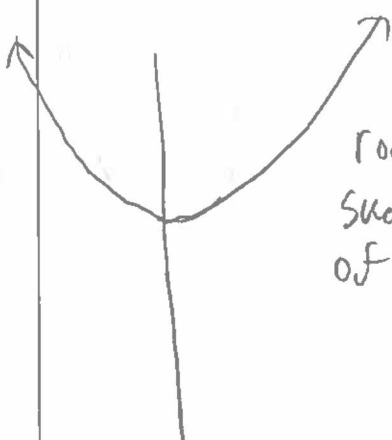
Problem 5) [10pts] Consider a mass M connected to a a spring which has the following potential energy function (no other forces are present)

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

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

Stable Equilibrium at $x=0$.

$E_T = \frac{1}{2}mv^2 + U(x)$



rough sketch of $U(x)$

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

$k = \frac{\left(6\alpha\sqrt{1+\frac{x^2}{x_0}} - 1\right)}{x^2}$

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

$T = 2\pi\sqrt{\frac{Mx^2}{6\alpha\sqrt{1+\frac{x^2}{x_0}} - 1}}$

$T = 2\pi\sqrt{\frac{M}{6\alpha T x_0}}$

-additional space for calculation-