Physics 1B - S2012 - Lecture 2

First Midterm Exam - Wednesday, April 25

The exam lasts 50 minutes. You may consult both sides of a single 3″ × 5″ notecard, otherwise the exam is closed book and closed notes. A calculator may be used for graphing and calculations.

Show all your work in order to receive credit for your answer. Include the correct units on numerical answers, indicate the direction of vector quantities, and clearly indicate your final answer.

Do not begin the exam until everyone is instructed to do so. Your signature below indicates your adherence to the University's policies of academic integrity.

The exam consists of three problems.

Name: SOLUTIONS

Signature: ______________________

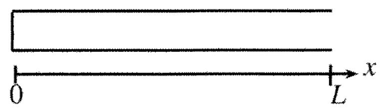
Student ID #: ______________________

Wen

Justin

Question Number	Maximum Points	Points Earned
1	30	
2	30	
3	30	
Total:	90	

1. A pipe lies along the x-axis and has a length L. The pipe is closed (no speaker, just closed) at $x = 0$ m and open to the room temperature air at $x = L$.



Standing sound waves in the pipe are described by

$$\Delta p(x,t) = A \sin(kx + \phi) \cos \omega t,$$

where Δp is the pressure variation from atmospheric pressure.

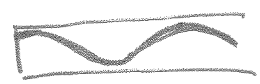
At $t = 0$ s, the pressure variation at the closed end has the value $p_{\max}$.

I assume $p_{max} > 0$.

(a.) Give an approximate numerical value for ω/k.

$\omega/k = v_{sound} \simeq 344$ m/s @ room temp.

(b.) Determine the unknown quantity A.

pressure wave @ $t=0$: 

closed end is a pressure antinode.

$A = p_{max}$

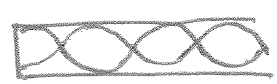
(c.) Determine the unknown quantity ϕ.

closed end is a pressure antinode.

$\sin(kx+\phi) = \cos kx$

$\Rightarrow \phi = +\pi/2$

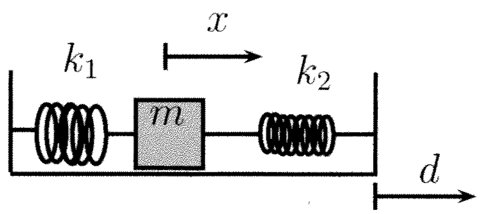
(d.) Find an expression for k.

closed end is pressure antinode, open end is pressure node!  for example

$\Rightarrow L = n\lambda/4$ for $n = 1, 3, 5, \ldots$

$k = \frac{2\pi}{\lambda} = n\frac{\pi}{4L}$

2. A mass is held between a pair of springs on a frictionless platform, as in the figure.



(a.) If the platform is at rest, find the angular frequency of the oscillating mass.

$$F(x) = -k_1 x - k_2 x = -(k_1+k_2)x$$

S.H.M. w/ $\omega^2 = \frac{k}{m} = \frac{k_1+k_2}{m}$

$$\omega = \sqrt{\frac{k_1+k_2}{m}}$$

The platform now oscillates horizontally, where the position of the platform is given by $d(t) = D\cos 10\pi t$.

(b.) Write the differential equation (Newton's 2nd Law) which describes the mass's motion from equilibrium $x(t)$. Do not solve for $x(t)$.

$$F(x) = -(k_1+k_2)(x-d)$$
$$= -(k_1+k_2)(x - D\cos 10\pi t)$$

$$\Rightarrow m\frac{d^2x}{dt^2} = -(k_1+k_2)x + (k_1+k_2)D\cos 10\pi t$$

(c.) As the platform oscillates, what is the period of the mass?

According to the result of b, the mass is driven by a force $F(t) = (k_1+k_2)D\cos 10\pi t$.

ω_d
m

Driving freq. matches the mass's freq., $T = \frac{2\pi}{\omega_d} = \frac{1}{5}$ s

(d.) As the platform oscillates, what is the amplitude for the mass?

driving force amplitude: $F_{max} = (k_1+k_2)D$.

$\omega_d = 10\pi$.

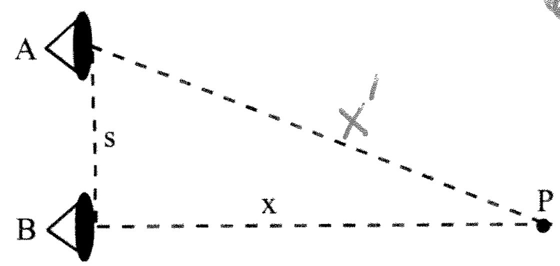
$b = 0$.

$k = k_1+k_2$

$$A = \frac{F_{max}}{k - m\omega_d^2}$$

3. A pair of 100 W speakers are in phase and both produce sound at 500 Hz. Each speaker acts as a source of spherical sound waves. The speakers are separated by a variable distance s. A listener is located at point P, $x = 2.00$ m directly in front of speaker B (see figure).

I use $v = 344$ m/s, $f = 500$ Hz



(a.) Find the smallest s for which the minimum sound intensity reaches the listener.

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destructive int.

destructive int. occurs for path diff. of $n\frac{\lambda}{2}$ $(n=1,3,\ldots)$

minimum path difference: $x' - x = \lambda/2 = \frac{1}{2}\frac{v}{f} = 0.344\,\text{m}$

$\Rightarrow \sqrt{s^2+x^2} - x = 0.344\,\text{m} \Rightarrow s = 1.22\,\text{m}$

(b.) What would be the intensity at the listener from speaker B alone?

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$I(r=x) = \frac{P_B}{4\pi x^2} = \frac{100\,\text{W}}{4\pi(4\,\text{m}^2)} = 1.99\,\text{W/m}^2$

(c.) Find the next-highest frequency above 500 Hz for which the listener receives maximum sound intensity. Assume the speakers are at separation s from part (a).

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constructive int. occurs for $x' - x = n\lambda$

$(n = 0, 1, 2\ldots)$

i.e. $\lambda_{con.} = \frac{\lambda_{dest}}{2}$

$\Rightarrow$ double original freq. to ensure constructive int.

1000 Hz