SOLUTIONS

PHYS 2112; Spring 2019 **Exam 2** **February 26, 2019**

Last Name (print)________________________ **First Name** (print)________________________

Signature ________________________ LSUID No. ________________________

TURN OFF AND PUT AWAY ANY AND ALL NONAPPROVED ELECTRONIC DEVICES.

Have your LSU ID ready when you turn in your paper.

You may only use an ordinary scientific or graphing calculator. *You may not use a cell phone, smart phone, or tablet application as your calculator.*

Examine your paper to be sure it is complete and legible. There should be 12 multiple-choice questions and 2 free-response problems points. There are 6 pages, including the cover sheet.

Circle one:

MWF 11:30 am (S. Marley)

MWF 1:30 pm (M. Gaarde)

TTh 9:30 am (P. Sprunger)

For the multiple choice questions, bubble in the correct answer on your ScanTron for each question. There is room on the exam for scratch work or calculations, but that work will not be checked or graded. Partial credit may be awarded on multiple-choice questions, but this partial credit will be based on the answers that you have bubbled in on the ScanTron and NOT on your scratch work on the exam itself.

For the free-response problems, show all relevant work in the space provided. Without supporting work, even a correct answer will receive little or no credit. Partial credit will be awarded as warranted. If your work for a problem is somewhere other than the space provided for that part of the problem, you must indicate where your work is located. For example, if you need more room for your solution, then you may write on the back of the page. Be sure to add a note to this effect; otherwise, anything on the back of the paper will be regarded as scratch work and will not be checked or graded.

Be sure that numerical answers appear with appropriate **SI units**. Points will be deducted for missing, incorrect, or "silly" units. If the final answer is, in fact, a dimensionless quantity, please write the numerical result followed by the word dimensionless.

You will have 60 minutes to complete this examination.

→ ***Your free response will be graded for consistency. That is, if you need a quantity from a previous part and didn't get it right or could not complete it, you will be graded on your work for the part you are working on.***

Question #1 (no points) Bubble in the answer choice corresponding to your class section number.

A. Sec. 1; MWF 11:30 am (S. Marley)
B. Sec. 2; MWF 1:30 pm (M. Gaarde)
C. Sec. 3; TuTh 9:00 am (P. Sprunger)

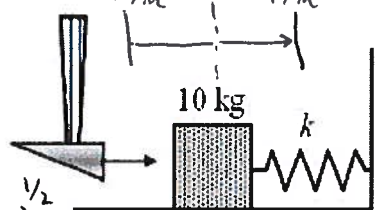
Question #2 (no points)
Your version of the test is **A**. Bubble in answer **A** on your ScanTron.

Question #3 (5 points) Which one of the following statements is *true* concerning an object executing simple harmonic motion?~~The object's maximum acceleration is equal to its maximum velocity.~~

A. The object's velocity is never zero.
B. The object's velocity and acceleration are simultaneously zero.
(C.) The object's velocity is zero when its acceleration is a maximum.
D. The object's acceleration is never zero.

$v(t) = -\omega x_m \sin(\omega t + \phi)$
↳ min value (0) @ $\omega t + \phi = n\pi$
$a(t) = -\omega^2 x_m \cos(\omega t + \phi)$
↳ @ $t = \frac{1}{\omega}(n\pi - \phi)$ $|a(t)| = |-\omega^2 x_m|$ → max

Question #4 (5 points) A 10-kg box is at rest at the end of an unstretched spring with constant k = 4000 N/m. The mass is struck with a hammer giving it a velocity of 6.0 m/s to the right across a frictionless surface. What is the amplitude of the resulting oscillation of this system?

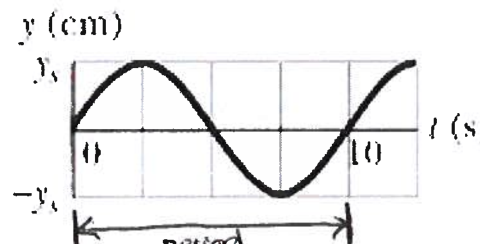


A. 0.5 m
B. 2 m
(C.) 0.3 m
D. 0.6 m
E. 0.4 m

$\frac{1}{2} m v^2 = \frac{1}{2} k x_m^2$

$x_m = v\sqrt{\frac{m}{k}} = (6\ \text{m/s})\left(\frac{10\ \text{kg}}{4000\ \text{N/m}}\right)^{1/2} = (6\ \frac{\text{m}}{\text{s}})\left(\frac{1\ \text{kg}}{400\ \text{N/m}}\right)^{1/2}$ → $x_m = 0.3$ m

Question #5 (5 points) A sinusoidal transverse wave travels along a string with a velocity of 9.5 cm/s. The displacement y of the string particle at x = 0 is given in the figure as function of time t. What is the wavelength of the traveling wave?



A. 0.48 m
(B.) 0.95 m
C. 0.24 m
D. 1.80 m
E. 6.61 m

T = 10 s

$v = \frac{\omega}{k} = \frac{2\pi/T}{2\pi/\lambda} = \frac{\lambda}{T}$

$\lambda = Tv = (10\ \text{s})(0.095\ \text{m/s}) = 0.95$ m

Question #6 (5 points) A wave moves at a constant speed along a string. Which one of the following statements is false concerning the motion of particles in the string?

A. The particle speed depends on the frequency of the periodic motion of the source.
B. The particle speed is not the same as the wave speed.
C. The particle speed depends on the amplitude of the periodic motion of the source.
D. The particle speed is independent of the tension and linear density of the string.
(E.) The particle speed is constant.

particle speed = $u(x,t)$ (not v_{wave}!)

$u(x,t) = \frac{\partial}{\partial t} y(x,t) = \frac{\partial}{\partial t} y_m \sin(kx \mp \omega t + \phi)$

$u(x,t) = \mp \omega y_m \cos(kx \mp \omega t + \phi)$

particle speed is not constant; it varies

Question #7 (5 points) A transverse periodic wave on a string with a linear density of 0.200 kg/m is described by the following equation: $y = 0.08 \sin(28.0x - 469t)$, where x and y are in meters and t is in seconds. What is the tension in the string?

A. 56.1 N
B. 65.8 N
C. 79.6 N
D. 3.99 N
E. 32.5 N

In general: $y = y_m \sin(kx \mp \omega t + \phi)$

here, sign is "−" → wave moving in positive-x direction

$y_m = 0.08\,m$ $\quad \phi = 0$

$k = 28$ rad/m

$\omega = 469$ rad/s

$v = \frac{\omega}{k} = \sqrt{\frac{T}{\mu}} \rightarrow T = \mu\left(\frac{\omega}{k}\right)^2 = (0.2\,\frac{kg}{m})\left(\frac{469\,s^{-1}}{28\,m^{-1}}\right)^2 = 56.11\,N$

Question #8 (5 points): Two sinusoidal waves have the same angular frequency, the same amplitude y_m, and travel in the same direction in the same medium. If they differ in phase by 50°, the amplitude of the resultant wave is given by:

A. $0.64\,y_m$
B. $1.3\,y_m$
C. $0.91\,y_m$
D. $1.8\,y_m$
E. $0.35\,y_m$

↳ Interference of waves!

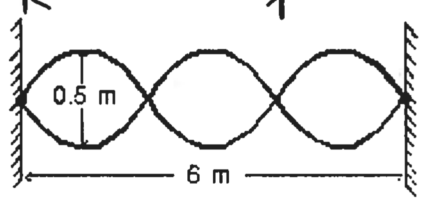
$y'(x,t) = [2y_m \cos\frac{\phi}{2}] \sin(kx - \omega t + \frac{\phi}{2})$

Amplitude

$2y_m \cos\left(\frac{\phi}{2}\right) = 2y_m \cos\left(\frac{50^\circ}{2}\right) = 2y_m(0.906) = 1.81\,y_m$

Question #9 (5 points) A standing wave pattern is established in a string as shown. The wavelength of one of the component traveling waves is:

A. 0.25 m
B. 0.5 m
C. 1 m
D. 2 m
E. 4 m



3 nodes in 6 m

$\frac{3\lambda}{2} = 6\,m$

$\lambda = \frac{12\,m}{3} = 4\,m$

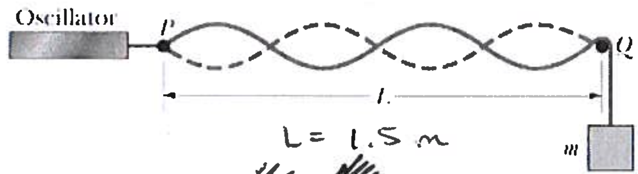
distance between each node is $\frac{\lambda}{2}$

Question #10 (5 points)
A microphone of surface area 2.0 cm^2 absorbs 1.1 mW of sound. What is the intensity of sound hitting the microphone?

A. 2.2×10^{-5} W/m^2
B. 0.55 W/m^2
C. 2.2 W/m^2
D. 2.8 W/m^2
E. 5.5 W/m^2

$I = \frac{P}{A} = \frac{1.1\,mW}{2.0\,cm^2} = \frac{1.1\times10^{-3}\,W}{2.0\,cm^2\left(\frac{0.01\,m}{1\,cm}\right)^2} = \frac{1.1\times10^{-3}\,W}{2\times10^{-4}\,m^2} = 5.5\,W/m^2$

Question #11 (5 points) A string with linear density 2.0 g/m is tied to a sinusoidal oscillator (point P) and runs over a support (point Q) and is stretched by weight that provides a tension τ. If the length (*L*) is 1.5 m and the oscillator frequency is 210 Hz, what tension allows the oscillator to set up the fourth harmonic on the string?



A. 108.1 N
B. 4.41 N
C. 49.6 N
D. 73.1 N
E. 13.3 N

$v = f_n \lambda_n = \sqrt{\frac{\tau}{\mu}}$

$\tau = (f_4 \lambda_4)^2 \mu$

$= [(210\,Hz)(0.75\,m)]^2 (0.002\,\frac{kg}{m})$

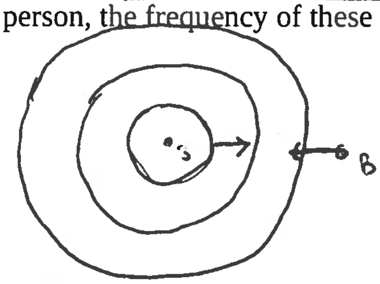
$= 49.6\,N$

$L = 1.5\,m$

$\frac{4\lambda}{2} = L \rightarrow \lambda = L/2 = 0.75\,m$

Question #12 (5 points) A stationary source S generates circular outgoing waves on a lake. The wave speed is 5.0 m/s and the crest-to-crest distance is 2.0 m. A person in a motor boat heads directly toward S at 3.0 m/s. To this person, the frequency of these waves is:

A. 4.0 Hz
B. 1.5 Hz
C. 2.0 Hz
D. 1.0 Hz
E. 8.0 Hz



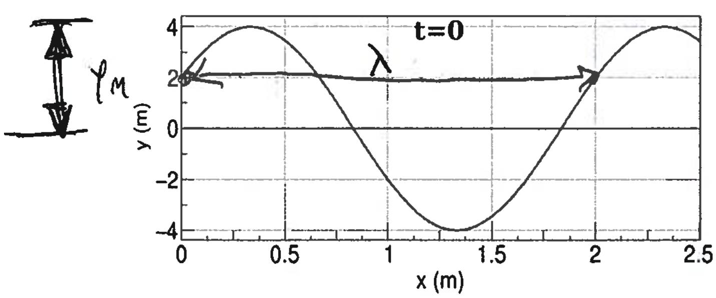
$\lambda = 2\,m$

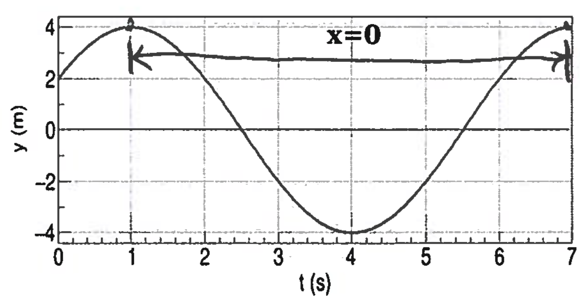
$V_{wave} = 5\,m/s$, $V_{boat} = V_{detector} = 3\,m/s$

$f_{waves} = \frac{V_{wave}}{\lambda} = \frac{5\,m/s}{2\,m} = 2.5\,Hz$

$f'_{(boat)} = f_{wave}\left(\frac{V_{wave} + V_D}{V_{wave}}\right) = (2.5\,Hz)\left(\frac{5+3\,m/s}{5\,m/s}\right)$
$= (2.5\,Hz)(1.6) = 4\,Hz$

Problem #1 (30 points) – Show your work!





A transverse wave propagates along a string of linear mass density 0.077 kg/m in the positive-x direction. The displacement of the string at $t = 0$ s and $x = 0$ cm is shown in the figures below (note the units on the axes!). Determine the following quantities.

A. (6 points) From simply looking at the graphs, what is the period (T), wavelength (λ), and amplitude (y_m) of the wave?

$T = 6\,s$, $\lambda = 2\,m$, $y_m = 4\,m$

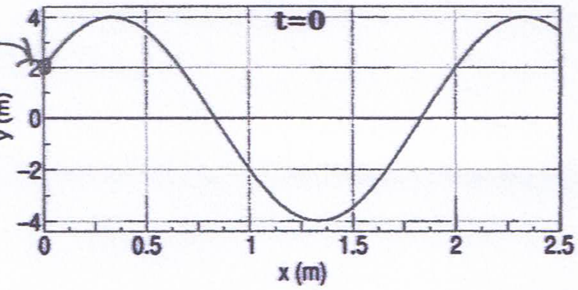
B. (4 points) What are the wave number (k) and angular frequency (ω) of the wave?

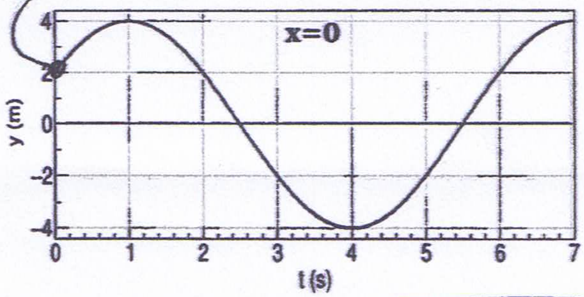
$k = 2\pi/\lambda = 2\pi/2\,m = \pi\ rad/m$

$\omega = 2\pi/T = 2\pi/6\,s = \frac{\pi}{3}\ rad/s$

Problem #1 Continued (30 points) – Show your work!

y(0,0)





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✓ ✓ ✓ ?

C. (5 points) What is the full equation for the transverse displacement, $y(x,t) = y_m \sin(kx \pm \omega t + \phi)$ for this wave?

find $\phi \rightarrow y(x=0, t=0) = y_m \sin(\phi) = 2\,m$ (from graph)

$\sin\phi = \frac{2\,m}{4\,m}$

$\phi = \sin^{-1}(\frac{1}{2}) = 30° = \frac{\pi}{6}$ rad

Full equation

$y(x,t) = (4\,m)\sin(\pi x - \frac{\pi}{3}t + \frac{\pi}{6})$

→ minus sign used because wave moving in positive-x direction

D. (5 points) What is the wave speed?

$v_w = \frac{\omega}{k} = \frac{\lambda}{T} = \frac{2\,m}{6\,s} = 0.333\ m/s$

E. (5 points) What is the average power transmitted by the wave?

$P_{avg} = \frac{1}{2}\mu v \omega^2 y_m^2 = \frac{1}{2}(0.077\,\frac{kg}{m})(0.333\,\frac{m}{s})(\frac{\pi}{3}\,\frac{rad}{s})^2(4\,m)^2$

$= 0.225\ W$

F. (5 points) What is the maximum transverse speed of the string?

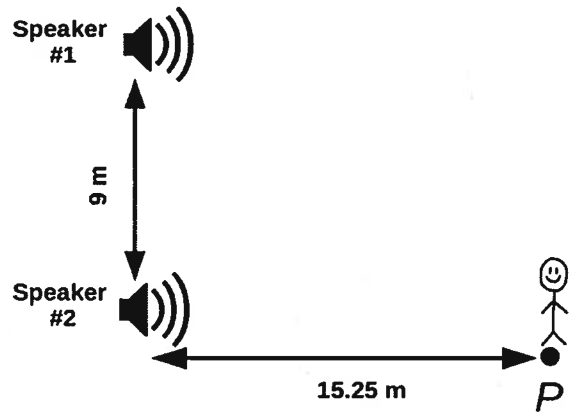
$u(x,t) = -\omega y_m \cos(kx - \omega t + \phi)$

u(x,t) is maximum whenever $kx - \omega t + \phi$ is an integer multiple of π → then $\cos(\;) = \pm 1$

$|u(x,t)|_{max} = |-\omega y_m| \rightarrow = (\frac{\pi}{3}\,\frac{(rad)}{s})(4\,m)$

$= \frac{4\pi}{3}\ m/s \simeq 4.2\ m/s$

Problem #2 (20 Points) – Show your work!!!



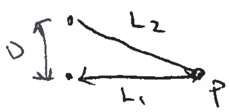
Dennis is a sound engineer setting up an outdoor concert. Two speakers on the stage are setup to play a loud "high C" note (f = 1046.5 Hz). Dennis is positioned as in the diagram at point P. The velocity of sound in air is 343 m/s.

a) (4 points) What is the wavelength of the sound waves emitted by the speakers?

$$v = f\lambda$$

$$\lambda = \frac{v}{f} = \frac{343\ m/s}{1046.5\ 1/s} = \underline{0.328\ m}$$

b) (5 points) Calculate the phase difference between the waves that reach Dennis where he is standing (Point P).



$$L_2 = \sqrt{L_1^2 + D^2} = \sqrt{(15.25m)^2 + 9^2 m} = 17.71\ m$$

$$\Delta L = L_2 - L_1 = 17.71_m - 15.25\ m = \underline{2.46\ m}$$

$$\phi = 2\pi \frac{\Delta L}{\lambda} = 2\pi \left(\frac{17.71 - 15.25}{0.328}\right)$$

$$= 2\pi\,(7.49) \simeq 15\pi$$

c) (6 points) What is the resulting type of interference that Dennis experiences: Fully Constructive, Fully Destructive, or Intermediate? (Support your answer!)

At point P: $s'(x,t) = \underbrace{\left[2 s_m \cos\frac{\phi}{2}\right]}_{\text{Amplitude}} \cos\left(kx - \omega t + \frac{\phi}{2}\right)$

Amplitude →
0 = fully destructive
$2s_m$ = fully constructive
others = Intermediate

In this case: $2 s_m \cos\left[\frac{15\pi}{2}\right] = 0$

Fully destructive

d) (5 points) Speaker #1 stops working and Dennis runs away from Speaker #2 to his van to get a suitable replacement. If Dennis is running with a constant speed of 5 m/s, what is the frequency (in Hertz) that he perceives as he runs away?

$f = 1046.5$ Hz , $v = 343$ m/s , $V_{Dennis} = 5$ m/s

$$f' = f\left(\frac{v - v_D}{v}\right) = (1046.5\ Hz)\left(\frac{343\ m/s - 5\ m/s}{343\ m/s}\right)$$

$$= (1046.5\ Hz)(0.985)$$

$$\boxed{f' = 1031.3\ Hz}$$