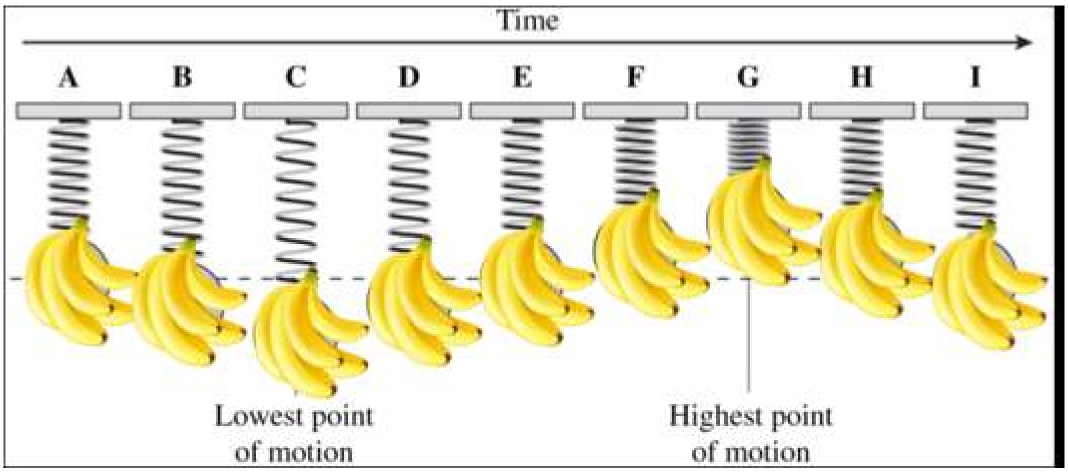
Physics 221 – Spring 2013
Exam 1

Name: ______________________________

Questions 1-7 use the following scenario:

A bunch of bananas is oscillating on a spring with a spring constant of 50 N/m. The equations of motion for the bananas are:

$y = 0.25\text{m} \sin(6.45\,t)$ $v = 1.61\text{m/s} \cos(6.45\,t)$ $a = -10.4\text{m/s}^2 \sin(6.45\,t)$



1) What is the mechanical energy of the oscillating bananas?

$x = A\cos(2\pi f\,t)$ is the general form. So A (amplitude) = 0.25m

$\frac{1}{2}kx^2$ is the potential energy. When the spring is compressed or stretched the most, then all the mechanical energy is in the form of potential energy. The maximum compression/stretching is at the amplitude

$\frac{1}{2}$ 50 N/m $(0.25\text{m})^2$ = **1.56 J**

2) The period of oscillation is

$x = A\cos(2\pi f\,t)$ is the general form. $6.45 = 2\pi f$ which means $f = 1.027$ Hz.

*$T = 1/f$ so **T** =* **0.97 s**

3) At which of the above times is the velocity zero?

The velocity is zero when the bananas are turning around. So the lowest and the highest points which are **C and G.**

4) At which of the above times is the acceleration zero?

The acceleration is zero when there is no force. The only time there is no force is when the spring is not stretched or compressed which would be at equilibrium **A, E and I**

5) What is the maximum acceleration of the bananas?

The maximum acceleration is **10.4 m/s²** This can be seen from the acceleration equation above. The largest it can be is the coefficient in front of the cos argument.

6) What is the velocity of the bananas at 4.0 s?

$v = 1.61\text{m/s} \cos(6.45\,t)$ plug in 4.0s for t and make sure you're in radians**!** **1.26 m/s**

7) What is the mass of the bananas?

The maximum velocity is 1.61 m/s as seen from the velocity equation above. The maximum velocity is the point where all the energy is kinetic and the spring is neither compressed nor stretched. So we can set ½ mv_{max}^2 to find the total mechanical energy which we found in #1 above to be 1.56J
$m = 1.56J *2 / (1.61\ m/s^2)^2$ **= 1.2 kg**

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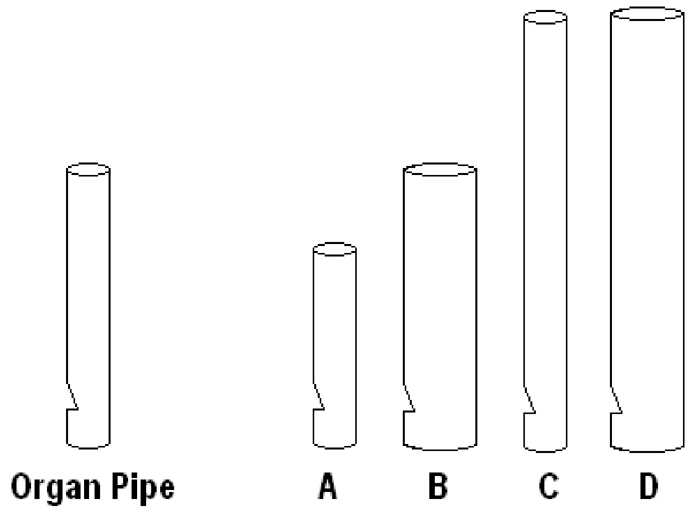
8) Consider resonance and sympathetic vibration
   a) Resonance is a specific case of sympathetic vibration
   b) Sympathetic vibration is a specific case of resonance
   c) These two phenomena are independent



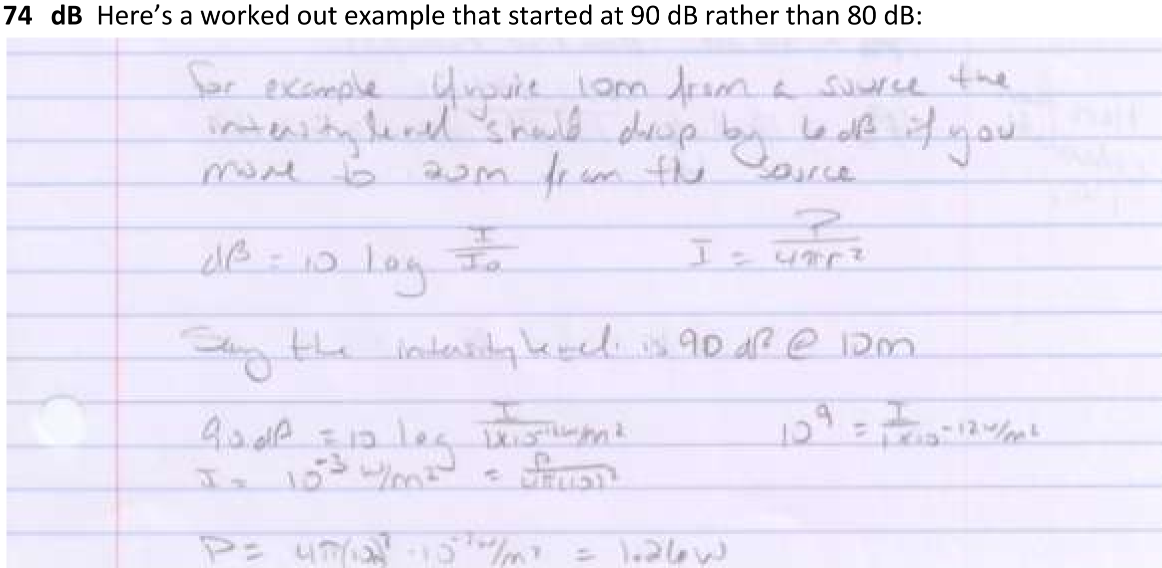
9) If a person blows over the top of the pipes shown in the diagram, which pipe will make a lower (pitch) sound?

   Both C & D

10) Based on what you learned about elephant's hearing, one would expect a squirrel's ears to be sensitive to a frequency range
   higher than humans

11) If a person begins at a position that is 10 feet from the cause of a loud sound and then moves to a position that is 20 feet from the cause of the sound (twice as far away) the sound will be
   ¼ as intense *because intensity goes as* $1/r^2$

12) In the situation above where the person moves twice as far away from a sound, the intensity level measured in decibels was 80 dB when the person was 10 feet from the source. What is the intensity level when they are 20 feet from the source?
   74 dB Here's a worked out example that started at 90 dB rather than 80 dB:



For example if you're 10m from a source the intensity level should drop by 6 dB if you move to 20m from the source

$dB = 10 \log \frac{I}{I_o}$ $\qquad I = \frac{P}{4\pi r^2}$

Say the intensity level is 90 dB @ 10m

$90\ dB = 10 \log \frac{I}{1\times10^{-12} W/m^2}$ $\qquad 10^9 = \frac{I}{1\times10^{-12} W/m^2}$

$I = 10^{-3} W/m^2 = \frac{P}{4\pi(10)^2}$

$P = 4\pi(10)^2 \cdot 10^{-3} W/m^2 = 1.26 W$

Power of the source is 1.26W

@ 20m what is the intensity level?

$I = \frac{1.26W}{4\pi(20)^2} = 2.5 \times 10^{-4} W/m^2$

$dB = 10 \log \frac{2.5 \times 10^{-4} W/m^2}{1 \times 10^{-12} W/m^2} = 84 dB$

So yes 6 dB loss when distance was doubled

13) If one person plays a trumpet and then a second person, right next to them, also begins playing a trumpet, the sound will be

Twice as intense

14) In the example above assume the intensity level measured in decibels for one trumpet is 80dB for the listener. When two people begin playing the intensity level for the listener will be

83 dB Here's an example of the math if the intensity is cut in half rather than doubled:

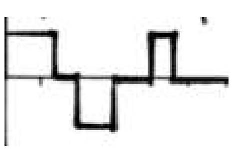
Cut power or Intensity in half the intensity level (dB) drops by 3 dB.

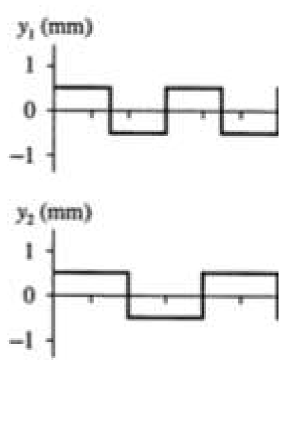
$I_A = 1 \times 10^{-3} W/m^2 \quad \frac{1}{2} I_A = I_B = 0.5 \times 10^{-3} W/m^2$

$dB_A = 90 dB$ (from last example)

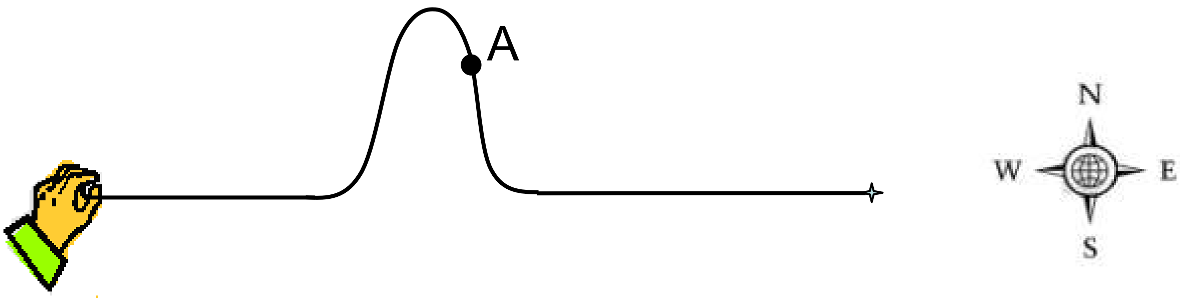
$dB_B = 10 \log \frac{0.5 \times 10^{-3} W/m^2}{1 \times 10^{-12} W/m^2} = 87 dB$

15) Two waves arrive simultaneously at a point in space from two different sources as shown to the right. The resultant wave would be





The figure below shows a rope on a tile floor with a knot at point A. Someone has shaken the end sideways to make a pulse. You are looking down and taking a movie of the motion. Below is one freeze frame of the movie.



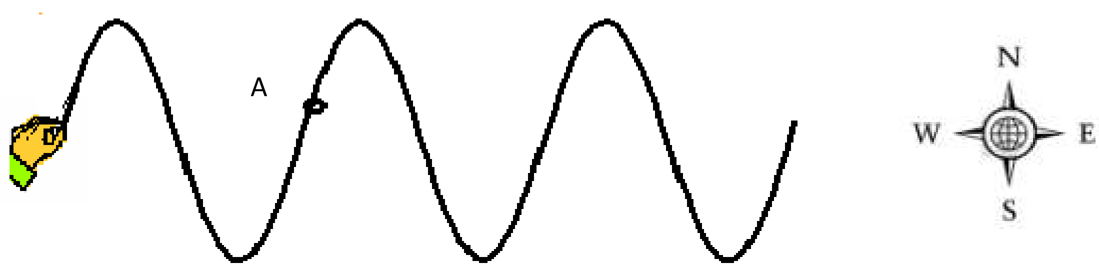
16) If you advance the movie one frame, the knot at point A would be further to the
    a) **North** b) South c) East d) West e) in the same place.

17) If the person generates a new pulse like the first but more quickly, the pulse would be
    a) same size b) wider c) **narrower**

18) If the person generates another pulse like the first but he moves his hand further, the pulse would be
    a) same size **b) taller** c) shorter

19) If the person generates another pulse like the first but the rope is tightened, the pulse will move
    a) at the same rate b**) faster** c) slower

Now the person moves his hand back and forth several times to produce several waves. You freeze the movie and get this snapshot.



20) If you advance the movie one frame, the knot at point A would be further to the
    a) in the same place b) North **c) South** d) East e)West

21) If you advance the movie one frame, the pattern of the waves will be _________relative to the hand.
    a) in the same place
    b) shifted North
    c) shifted South
    d) shifted East
    e) shifted West

22) If the person starts over and moves his hand more quickly, the peaks of the waves will be
    a) the same distance apart b) further apart c) **closer together**

A particular string on a guitar is 85 centimeters long before it's placed on the guitar and 63 cm is available to vibrate when plucked after it's been attached and wound to the tuning pin on the guitar. The Tension of the string when tuned to have a fundamental of A_2 - 110 Hz is 160 Newtons.

23) What is the wave speed?

The relevant equations are $v = \sqrt{\frac{T}{\mu}}$ $v = \lambda f$

$v = \lambda f$ = 2*0.63m * 110 Hz = **139 m/s**

The fundamental is the longest wavelength that will resonate on a taught string. The longest will be when half a wavelength is between the two anchor points of the string. This string has 63 cm available to vibrate (the rest is wound around the pin).

24) If the wave speed for a different string, E_4 -329.6 Hz, was found to be 415 m/s and its tension is 70 Newtons, what is the mass of the string? Assume the lengths are as stated above (85 cm unwound and 63 cm can vibrate when attached.)

$v = \sqrt{\frac{T}{\mu}}$ where T is the tension (given as 70 N) and μ is the mass density which is mass/length. The mass of the string is for the whole string which is 85 cm long.

$\mu = m/L = T/v^2$ so $m = TL/v^2$ 70N * 0.85m / (415 m/s)^2 = **3.45 x 10^{-4} kg or 0.345 g**

25) Walter and his friend are moving across town. Walter is following the moving truck in his Audi. The truck goes through a yellow light and Walter has to stop. He honks his horn which emits 500Hz. What frequency does Walter hear when the sound bounces off the truck and back to his ears? The truck is moving at a steady 20 m/s. Use 340 m/s for the speed of sound.
There is basically a double Doppler shift here. The sound that is received by the moving truck is at a lower frequency because the truck is moving away. Then that sound is now the source which is lower to start with and is from a moving source. Walter now here's a lower sound because the source is moving.

$f' = f\frac{v \pm v_o}{v \pm v_s}$ + observer moving towards, - observer moving away,

- source moving towards, + source moving away.

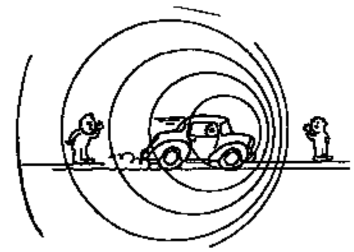
Sound the back of the truck receives f' = 500Hz $\frac{340\ m/s - 20\ m/s}{340\ m/s}$ = 470.6 Hz

Now the truck reflects this frequency back to Walter f' = 470.6 Hz $\frac{340\ m/s}{340\ m/s + 20\ m/s}$ = **444 Hz**

26) What is the Doppler Effect?

The Doppler Effect is when you hear a higher frequency as an object is approaching and a lower frequency as it is receding compared to the frequency being emitted by the source. The faster the speed difference between the observer and the source, the larger the frequency shift.

27) Why does the Doppler Effect happen? Please use diagrams to support your answer.



Consider the case where the source is approaching an observer, each crest of the wave is emitted closer to the observer than the last. This causes the received wavelength to be shorter and the receiver then hears a higher pitched sound. Vice versa if the source is moving away. The receiver could also be moving. If the receiver is moving towards the source, the waves are encountered more frequently thus a higher frequency is heard.

28) Describe echolocation and how it works.

Echolocation is when an animal emits calls out to the environment and listens to the echoes of those calls that return from various objects near them. They use these echoes to locate and identify the objects. The time it takes for the echoes to return and the frequency shift of the echoes tell them about the location and the velocity of the objects.

29) How can echolocation be used to identify how far away an object is?

The longer it takes for the echo to return, the farther the object is.

30) What would be advantages and disadvantages to using only very narrowly focused sound waves to echolocate. Do you think animals actually use narrow or wide beams of sound to echolocate?

With a narrow focused beam of sound, all of the sound intensity is focused in one area. This gives more intense/louder sounds but covers a smaller area. The smaller area can be an advantage however, for identifying the exact location of the object and the size of the object. Similar to a flashlight. If you focus the beam into a narrow spot, it's brighter but it also illuminates a smaller area.

$v = 331\ \text{m/s}\sqrt{1+\frac{T}{273}}$ T in degrees Celsius

$F = -kx$ $a = -\frac{k}{m}x$ $T = 1/f$

Springs: $T = 2\pi\sqrt{\frac{m}{k}}$ $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ pendulum: $T = 2\pi\sqrt{\frac{L}{g}}$ $f = \frac{1}{2\pi}\sqrt{\frac{g}{L}}$ $g = 9.8\ m/s^2$

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

Equations of motion general: $x = A\cos(2\pi f t)$ $v = -2\pi f A\sin(2\pi f t)$ $a = -(2\pi f)^2 A\cos(2\pi f t)$

$v_{max} = 2\pi f A$ $a_{max} = A(2\pi f)^2$

$v = \sqrt{\frac{T}{\mu}}$ $v = \lambda f$

$I = \frac{P}{4\pi r^2}$ $\beta = 10\log\left(\frac{I}{I_o}\right)$ $I_o = 1 \times 10^{-12}\ \text{W/m}^2$

$f' = f\frac{v \pm v_o}{v \pm v_s}$ + observer moving towards, - observer moving away,

- source moving towards, + source moving away.