Physics 221, Fall 2009

Quiz 4, Form: A

Name: Key

Date:

$G = 6.7 \times 10^{-11}$ N m^2/kg^2
1atm $= 1.01 \times 10^5$ Pa

MC/40 P/60 LAB/10
20 for each type

Section 1. Multiple Choice

1. Which of the following variables affects the speed of a wave on a string?
   - (a) wavelength
   - (b) frequency
   - (c) length
   - (d) tension
   - (e) linear density
   - (f) all of the above
   - (g) both (a) and (b)
   - (h) (a), (b), and (c)
   - (i) both (d) and (e)

2. A sinusoidal wave travels horizontally on a string with a frequency of 2 Hz. How long does it take for a piece of string to move from its highest point to its lowest point?
   - (a) 0.13 s
   - (b) 0.25 s
   - (c) 0.5 s
   - (d) 2.0 s
   - (e) 4.0 s

   $\Delta t = \frac{1}{2}T$

   $T = \frac{1}{2\,\text{Hz}} = 0.5$ s

   $\frac{1}{2}T = \frac{1}{2}(0.5\,\text{s}) = 0.25$ s

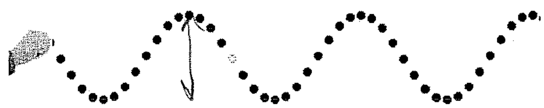
3. A longitudinal, sinusoidal sound wave in air has a speed of 340 m/s. If its frequency is 680 Hz, what is its wavelength?
   - (a) 2.0 m
   - (b) 2.3×10^5 m
   - (c) 340 m
   - (d) 0.5 m
   - (e) 0.0015 m

   $v = \lambda f$

   $\lambda = \frac{v}{f} = \frac{340\ \text{m/s}}{680\,\text{Hz}} = 0.5$ m

4. If a piece of the medium oscillates *parallel* to the direction of propagation of the wave, then the wave is a
   - (a) longitudinal wave.
   - (b) transverse wave.
   - (c) a combination of a longitudinal wave and transverse wave.
   - (d) a standing wave.
   - (e) a water wave.

5. In class, you analyzed the simulation shown below and you found that for a sinusoidal wave on a string, a piece of the string's motion is characterized by



   - (a) uniform motion (i.e. constant velocity).
   - (b) uniform circular motion.
   - (c) constant acceleration.
   - (d) simple harmonic motion.
   - (e) None of the above.

   each piece oscillates with Amplitude A, frequency f $y = A\cos(\omega t + \phi)$

6. For a standing sound wave in a pipe, at a location in the pipe where the displacement of an oscillating "piece" of air is an antinode, the air pressure
   - (a) is a node.
   - (b) is an antinode.
   - (c) could be a node or antinode.
   - (d) is neither a node nor an antinode.

7. Suppose that there is a standing sound wave in a pipe. For an open end of the pipe, the displacement of air

(a) is a node.
(b) is an antinode.
(c) could be a node or antinode.
(d) is neither a node nor an antinode.

pressure is a node, Patm
so displacement is an antinode

8. The overall length of a particular wind instrument is 40.0 cm. The resonating air column vibrates as in a pipe that is open at both ends. Find the frequency of the lowest note this instrument can play (the fundamental), assuming that the speed of sound in air is 340 m/s.

(a) 850 Hz
(b) 213 Hz
(c) 1275 Hz
(d) 8.5 Hz
(e) 425 Hz

$\lambda = \frac{2L}{n}$

$f = \frac{V}{\lambda} = \frac{nV}{2L}$

$f = \frac{340 \frac{m}{s}}{2(0.4m)} = 425 Hz$

9. Suppose that the first string of a guitar (E string) produces a fundamental frequency of 330 Hz and has a length of 0.8 m. If you want it to produce a frequency of 440 Hz (which is a factor of 4/3 greater than 330 Hz), what must be the length of the string? (You produce this length by pressing on the appropriate fret.)

(a) 0.2 m
(b) 0.4 m
(c) 0.5 m
(d) 0.6 m
(e) 0.75 m

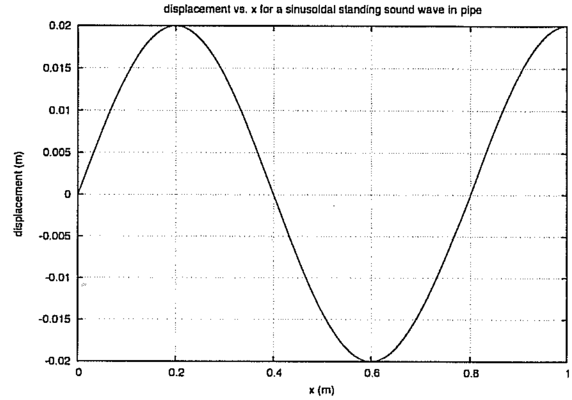
$f \propto \frac{1}{L}$

$L \propto \frac{1}{f}$

$\frac{1}{\frac{4}{3}f} = \frac{3}{4}\frac{1}{f} \Rightarrow \frac{3}{4}L$

$\frac{3}{4}(0.8) = 0.6 m$

10. The graph below shows the displacement as a function of position for a sinusoidal, longitudinal standing wave in a pipe.



Evidently,

(a) the pipe is open on both ends.
(b) the pipe is closed on both ends.
(c) the pipe is closed on the left end and open on the right end.
(d) the pipe is open on the left end and cosed on the right end.

11. Which harmonic is the longitudinal wave shown in the previous question?

(a) 1
(b) 3
(c) 5
(d) 7
(e) 9

$n = 1$

$n = 3$

$n = 5$

12. Air pressure at higher altitudes is

(a) greater than air pressure at sea level.
(b) less than air pressure at sea level.
(c) equal to air pressure at sea level.

13. What is the cause of the buoyant force by a fluid on an object?

(a) The compressibility of the fluid.
(b) The variation in density of the fluid between the top and bottom of the object.
(c) Drag due to motion of the object in the fluid.
(d) The difference in pressure between the top and bottom of the object.
(e) The difference in pressure between the depth of the object and the surface of the fluid.

P_{top} P_{bottom}

$F_B = F_{bottom} - F_{top}$

14. You hold a small, air-filled rubber ball so it is submerged at a depth of 0.5 m under the surface of the swimming pool. The buoyant force on the ball is F_B. If you swim to the bottom of the pool at a depth of 3 m, and hold the ball there on the bottom, the buoyant force on the ball is

(a) less.

(b) greater.

(c) the same.

F_B does not depend on depth

15. An empty helium-filled balloon has a mass of 0.015 kg. When filled with helium, it has a volume of 0.030 m^3. The density of helium at room temperature is 0.18 kg/m^3. What is the total mass of the balloon and helium?

(a) 0.020 kg

(b) 0.025 kg

(c) 0.005 kg

(d) 0.015 kg

(e) 0.010 kg

$m = m_{balloon} + m_{He} = (0.015) + (0.18)(0.03) = 0.015 + 0.005 = 0.020$ kg

16. The pressure at the surface of a swimming pool is atmospheric pressure (1.01×10^5 Pa). About how deep do you have to swim for the pressure to be 50% greater, or 1.5 times atmospheric pressure? (Use g=10 N/kg for simplicity.)

(a) 20 m

(b) 2 m

(c) 15 m

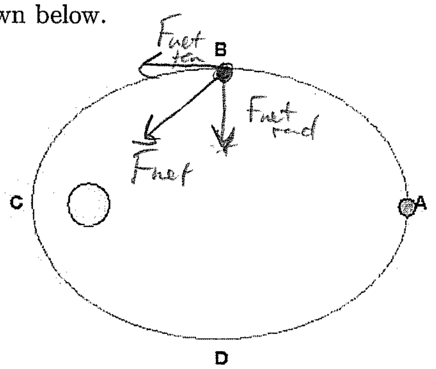
(d) 10 m

(e) 5 m

$\Delta P = \frac{1}{2} P_{atm} = \rho g h$

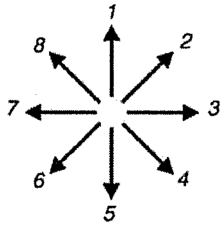
$h = \frac{\frac{1}{2}(1.01\times10^5)}{(1000)(10)} = 5$ m

Questions 17–20: A comet orbits the Sun as shown below.



Suppose that it is at ***point B*** and traveling ***counterclockwise***.

17. Which arrow points in the direction of the tangential component of the net force on the comet?



9 zero magnitude

(a) 1

(b) 3

(c) 5

(d) 7

(e) 8

18. Which arrow points in the direction of the perpendicular component of the net force on the comet?

(a) 1

(b) 3

(c) 5

(d) 7

(e) 8

19. Which arrow points in the direction of the velocity of the comet?

(a) 1

(b) 3

(c) 5

(d) 7

(e) 8

20. Is the comet speeding up or slowing down at this point?

(a) speeding up

(b) slowing down

(c) Neither, because at this point the tangential component of the net force is zero and the comet is in transition from speeding up to slowing down.

(d) Neither, because at this point the tangential component of the net force is zero and the comet is in transition from slowing down to speeding up.

21. A person on the "tea cup" amusement park ride rotates in uniform circular motion in a radius of 0.8 m with a period of 4.0 s. What is her linear speed?

(a) 0.4 m/s
(b) 0.2 m/s
(c) 3.2 m/s
(d) 1.57 m/s
(e) 1.26 m/s

22. For the person in the previous question, what is her angular speed?

(a) 0.4 rad/s
(b) 0.2 rad/s
(c) 3.2 rad/s
(d) 1.57 rad/s
(e) 1.26 rad/s

23. Using $F_{net,rad} = mv^2/r$ and Newton's law of gravitation, you can solve for the speed of an object, like a satellite or planet, that is in a circular orbit. When you do this derivation (and I suggest that you do it right now, what is the speed of an object in a circular orbit?

(a) $v = \sqrt{\frac{2GM}{r}}$
(b) $v = \sqrt{\frac{GMm}{r^2}}$
(c) $v = \sqrt{\frac{GM}{2r}}$
(d) $v = \sqrt{\frac{4\pi^2}{GM}r^3}$
(e) $v = \sqrt{\frac{GM}{r}}$

24. The volume of a water in a beaker is 50 cm^3. What is its volume in m^3

(a) 5×10^7 m^3
(b) 2×10^4 m^3
(c) 5×10^{-5} m^3
(d) 0.5 m^3
(e) 5000 m^3

25. How do astronomers measure the mass of the black hole at the center of our galaxy?

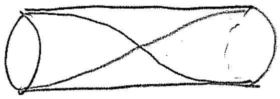
(a) By measuring the motion of a star orbiting the black hole and use Newton's second law to calculate the mass of the black hole.
(b) By dropping a beacon into the black hole that emits red light and measure the redshift of the light (into the IR region) as it falls toward the black hole.
(c) Using a very precise analytical balance.
(d) By sending a space probe to the black hole and crashing it into the black hole and interpretating data that it sends back before it breaks apart due to enormous gravitational forces.
(e) By putting it into a tank of water and measuring its percent body fat, using Archimedes' Principle.

Section 2. Problem Solving

26. A standing sound wave is created in an organ pipe that is open at both ends.

Displacement antinode at open end

(a) Sketch a picture of the pipe and sketch a graph of the displacement as a function of position along the pipe for the *first* harmonic, and write an expression for the wavelength of the standing wave in terms of the length of the pipe.

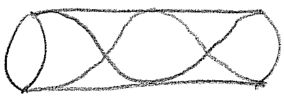


$\frac{1}{2}\lambda = L$

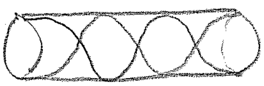
$\boxed{\lambda = 2L}$

(b) Sketch a picture of the pipe and sketch a graph of the displacement as a function of position along the pipe for the *second* harmonic, and write an expression for the wavelength of the standing wave in terms of the length of the pipe..

$\boxed{\lambda = L}$



(c) Sketch a picture of the pipe and sketch a graph of the displacement as a function of position along the pipe for the *third* harmonic, and write an expression for the wavelength of the standing wave in terms of the length of the pipe.



$\frac{3}{2}\lambda = L$

$\boxed{\lambda = \frac{2}{3}L}$

(d) Note how the wavelength of the different harmonics depends on L and derive an expression for wavelength as a function of L and the harmonic n.

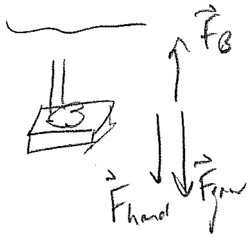
$\boxed{\lambda = \frac{2L}{n}}$ $n \equiv$ harmonic

(e) What is the frequency of the third harmonic, if the length of the pipe is 0.5 m and the speed of sound in air is 340 m/s?

$v = \lambda f$

$f = \frac{v}{\lambda} = \frac{340\ \frac{m}{s}}{\frac{2}{3}L} = \boxed{1020\ Hz}$

27. (a) An elderly person is exercising by holding a piece of styrofoam of volume 0.004 m^3 and density 100 kg/m^3 in equilibrium under water. The density of water is 1000 kg/m^3. What is the force by her hand on the styrofoam?



$$\vec{F}_{net} = \frac{\Delta \vec{p}}{\Delta t} = 0$$

$$\vec{F}_{net} = \vec{F}_B + \vec{F}_{grav} + \vec{F}_{hand}$$

$$y: \quad 0 = F_B - mg + F_{hand\,y}$$

$$F_{hand\,y} = mg - F_B = \rho_{sty} V_{sty} g - \rho_{water} g V_{sty}$$

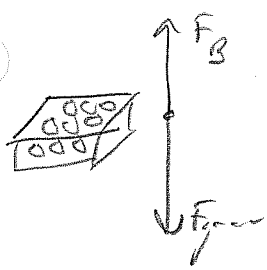
$$= (100\tfrac{kg}{m^3})(0.004\,m^3)(9.8) - (1000)(9.8)(0.004)$$

$$= 3.92\,N - 39.2\,N$$

$$= -35.28\,N$$

$F_{hand} = 35.3\,N$ in the $-y$ direction

(b) Suppose that she wants to impress her friends in the exercise group and make them think that she is really strong, so she adds large metal ball bearings to the styrofoam until it floats in equilibrium while completely submerged in the water, without her holding on to the stryofoam. If each ball bearing has a mass of 10 g, how many ball bearings must she add to the styrofoam so that it will float in equilibrium by itself without her holding on to it?



$$\vec{F}_{net} = \frac{d\vec{p}}{dt} = 0$$

$$F_B = F_{grav}$$

$$\rho_{water} g V_{object} = mg$$

$$m = \frac{\rho g V}{g} = \frac{(1000\,\tfrac{kg}{m^3})(9.8)(0.004)}{9.8}$$

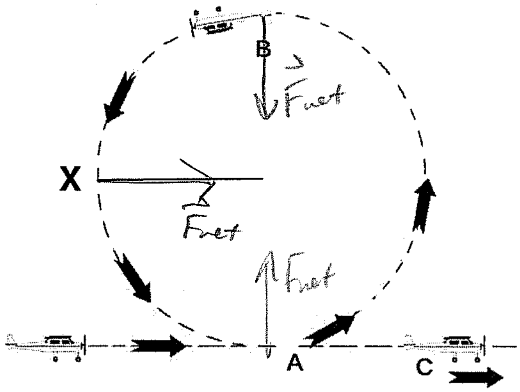
$$= 4\,kg$$

$$M = M_{styrofoam} + M_{ball\ bearings}, \quad M_{styrofoam} = \rho V = (100)(0.004) = 0.4\,kg$$

$$M_{ball\ bearings} = 4 - 0.4\,kg = \boxed{3.6\,kg}$$

$$\#\,BBs = \frac{3.6\,kg}{0.01\,kg} = \boxed{360 \text{ ball bearings}}$$

28. An airplane travels in a vertical loop at constant speed as shown below. The loop has a radius of 250 m, and the speed of the airplane is 60 m/s. The pilot's mass is 75 kg.



(a) Sketch the net force on the airplane at points A, B, and X in the diagram.

(b) The magnitude of the tangential component of the net force on the airplane at all points on its path is zero. Why?

$\vec{F}_{net} = \frac{d|\vec{p}|}{dt} \approx m\frac{d|\vec{v}|}{dt}$

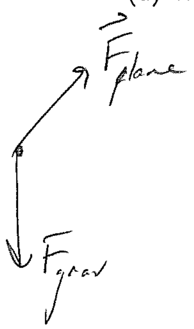
$|\vec{v}|$ is constant so $\frac{d|\vec{v}|}{dt} = 0$

(c) What is the net force on the pilot at point X? Express your answer as a vector.

$|\vec{F}_{net,rad}| = \frac{mv^2}{R} = \frac{(75)(60)^2}{250} = 1080\ N$

$\vec{F}_{net,rad} = \langle 1080, 0, 0 \rangle N$

(d) What is the force by the airplane on the pilot at point X? Express your answer as a vector.

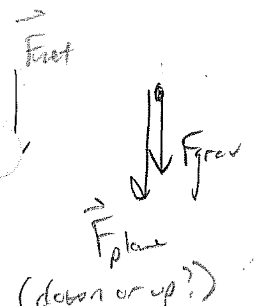


$\vec{F}_{net} = \vec{F}_{plane} + \vec{F}_{grav}$, $\vec{F}_{grav} = \langle 0, -mg, 0 \rangle$
$= \langle 0, -735, 0 \rangle N$

$\vec{F}_{plane} = \vec{F}_{net} - \vec{F}_{grav}$
$= \langle 1080, 0, 0 \rangle - \langle 0, -735, 0 \rangle$
$= \langle 1080, 735, 0 \rangle N$

(e) What is the force by the airplane on the pilot at point B?

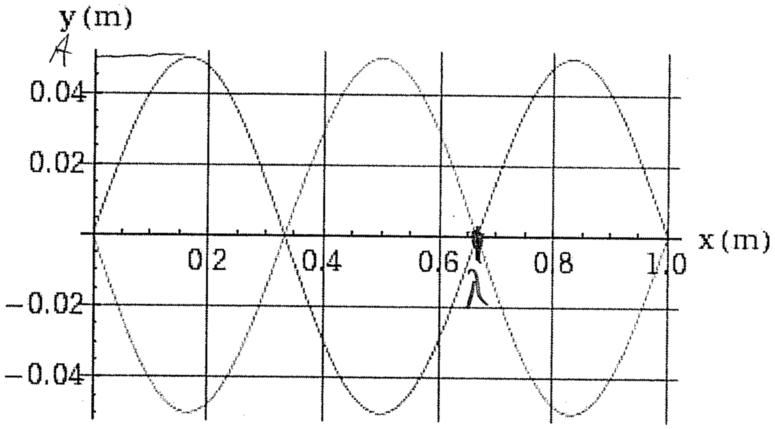
At point B,



$\vec{F}_{plane} = \vec{F}_{net} - \vec{F}_{grav}$
$= \langle 0, -1080, 0 \rangle - \langle 0, -735, 0 \rangle$
$= \langle 0, -345, 0 \rangle N$ downward!

Note: this is $\frac{345}{735} = 47\%$ of his weight! [illegible]

29. A standing wave on a 1.0 m long string is shown below. The wave is produced by an oscillator that is oscillating at 120 Hz.



(a) Which harmonic is this?

$n = 3$

(b) What is the wavelength of the wave?

$\frac{3}{2}\lambda = L$, $\lambda = \frac{2L}{3} = \frac{2}{3} = 0.67\,m$

You can see this on the graph too.

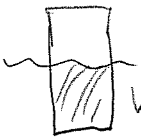
(c) What is the speed of the wave?

$v = \lambda f = (0.67\,\frac{m}{s})(120\,Hz) = 80\,\frac{m}{s}$

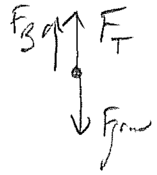
(d) What is the amplitude of the wave?

$A = 0.05\,m$

30. (a) Using a force sensor and string, you lower an aluminum cylinder into water so that exactly half the cylinder is submerged. If the weight of the cylinder (i.e. gravitational force by Earth on the cylinder) is 0.42 N and if the tension in the string is 0.34 N, what is the buoyant force on the cylinder?



$V_{submerged} = \frac{1}{2} V_{object}$



$F_B + F_T = F_{grav}$

$F_B = F_{grav} - F_T$

$= 0.42 - 0.34 = \boxed{0.08\ N}$

(b) If you lower the cylinder into the water so that it is completely submerged, what will be the buoyant force on the cylinder and what will be the tension in the string?

$2V$ gives $2F_B$ so $\boxed{F_B = 0.16\ N}$

$F_T = F_{grav} - F_B$

$= 0.42 - 0.16\ N$

$= \boxed{0.26\ N}$

31. You analyze data for the motion of Ganymede which is one of Jupiter's moons. It's x-position as a function of time is given by

$$x = (1.07 \times 10^9) cos((1 \times 10^{-5})t)$$

where x is in meters and t is in seconds.

(a) What is the angular speed of Ganymede?

$\boxed{\omega = 1 \times 10^{-5}\ \frac{rad}{s}}$

(b) What is the radius of Ganymede's orbit?

$\boxed{R = 1.07 \times 10^9\ m}$

(c) What is the period of Ganymede's orbit?

$\omega = \frac{2\pi}{T}$ so $\boxed{T = \frac{2\pi}{\omega} = 6.28 \times 10^5\ s} \approx 7.3$ days

(d) What is the linear speed of Ganymede?

$v = R\omega = (1.07 \times 10^9\ m)(1 \times 10^{-5}\ \frac{rad}{s}) = \boxed{1.07 \times 10^4\ \frac{m}{s}}$