TAKE HOME EXAM

This exam may not be discussed with anyone until 6pm Fri 11 Dec 2009.

Due Friday 11 Dec 2009 by noon EST. Your solutions should be left in the box on my office door, Room266.

This is an "open book" test, however you should realize that extensive use of reference materials may slow your progress substantially. You may not share solutions or discuss this exam in any fashion until Friday evening 11 Dec 2009 (6 pm EST). If you use a publicly accessible computer, you should not leave any remnants of your work.). If you use scratch sheets, you should not leave any remnants of your work that could be seen by another person. You should not engage in any activity which could give the appearance of cheating to any reasonable or unreasonable person.

You must turn in these question/problem statements with your solutions. You may attach additional paper if necessary or work the problem on the back of a test sheet.

To assure fairness to all, you may not ask me how to work related problems during the exam period. If you find a mistake, please let me know so that all can be notified via email.

Show ALL work. All work must be done on these test sheets. There is no way for you to receive credit for work that is not explicitly written down. I also recommend showing work for the multiple choice questions as partial credit may be possible on a few of them.

100 mph = 44.7 m/s, 1 inch = 2.54 cm, $\sin 30^\circ = 0.5$, $\sin 45^\circ = 0.707$, $\sin 60^\circ = 0.866$
G=6.67e-11 Nm^2/kg^2, M_{Earth}=5.96e+24 kg, M_{moon}=7.35e+22 kg, M_{Sun}=2.0e+30 kg
Radius of Moon=1740 km, Radius of Sun=6.96e+5 km, Radius of Earth=6370 km
1 eV = 1.602e-19 J, 1 hp = 746 W, c=3.00e+8 m/s

Moments of Inertia of Rolling Objects:

$I_{solid\ ball} = 2/5\ MR^2$ $I_{disk} = 1/2\ MR^2$ $I_{hoop} = MR^2$

Moments of Inertia of Rolling Objects spun about an edge:

$I_{rod\ about\ an\ end} = 1/3\ ML^2$ $I_{rectangle\ about\ an\ axis\ along\ edge} = 1/3\ Ma^2$

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READ CAREFULLY

TRUE/ FALSE

F 1. In simple harmonic motion, the period is proportional to the square of the amplitude.

T 2. In simple harmonic motion, the frequency does not depend on the amplitude.

T 3. In simple harmonic motion, the total energy is proportional to the square of the amplitude.

F 4. The motion of a simple pendulum is simple harmonic for any initial angular displacement.

T 5. The motion of a simple pendulum is periodic for any initial angular displacement.

T 6. If the acceleration of a particle is proportional to the displacement and is oppositely directed, the motion is simple harmonic.

T 7. The energy of a damped, un-driven oscillator decreases exponentially with time.

T 8. Resonance occurs when the driving frequency equals the natural frequency.

F 9. Sound waves in air are transverse waves of compression and rarefaction.

T 10. The beat frequency between two sound waves of nearly equal frequencies equals the difference in the frequencies of the individual sound sources.

T 11. The frequency of the fifth harmonic is 5 times the fundamental.

T 12. In a pipe that is open at one end and closed at the other, the even harmonics are not excited.

F 13. The Doppler shift in sound waves depends only on the relative motion of the source and the receiver.

T 14. Waves pulses on strings are transverse waves.

F 15. The speed of a harmonic wave on a string is proportional to the square of the amplitude of the wave.

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1 A vehicle heading down the highway at 80 km/h is being pursued by a police car that is right behind it, also traveling at 80 km/h If the cop's siren puts out a 500-Hz wail, what frequency will the perpetrator hear?

source → +80 observer → −80

a) < 500 Hz
b) 500 Hz
c) >500 Hz
d) none of these

$$f = f_0 \frac{V + u_{obs}}{V - u_{source}} = f_0 \frac{V + (-80)}{V - (+80)} = f_0$$

2. A pendulum is set to run accurately at sea level. It is then brought to the top of a high mountain, where it is found to

a) run slow
b) function unchanged
c) run fast
d) stop running
e) none of these

$T = 2\pi\sqrt{L/g}$

g gets smaller
T gets longer

3 The speed of waves on a stretched string _____ when the tension if doubled.

a) doubles
b) increases by a factor of 4
c) increases by a factor of 1.414
d) decreases by a factor of 2
e) none of these.

$V = \sqrt{\frac{T}{\mu}}$

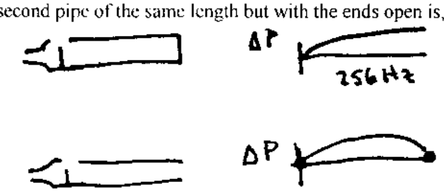
4. A simple pendulum is found to have a period of T_o. If the length of the pendulum is doubled, the new period is:

a) T_o
b) 2 T_o
c) 0.500 T_o
d) 1.414 T_o
e) 0.707 T_o

$T = 2\pi\sqrt{L/g}$

5. The fundamental frequency of the air in a pipe that has one end closed is 256 Hz. The fundamental frequency of a second pipe of the same length but with the ends open is, in Hz:

a) 64
b) 128
c) 256
d) 512
e) 1024



$f_0 = \frac{V}{4L}$

$f_0 = \frac{V}{2L}$

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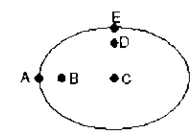
6. In planetary motion the line from the star to the planet sweeps out equal areas in equal times. This is a direct consequence of:

A) the conservation of energy
B) the conservation of momentum
C) the conservation of angular momentum
D) the conservation of mass
E) none of the above

7. The elliptical orbit of a planet around the Sun is shown on the diagram. Which letter labels the position of the sun?



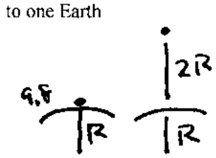
A) A
B) B
C) C
D) D
E) E

8. The approximate value of g (in m/s^2) at an altitude above Earth equal to one Earth diameter is:

A) 9.8
B) 4.9
C) 2.5
D) 1.9
E) 1.1

$|F| = G\frac{mM}{r^2} = m\left(\frac{GM}{r^2}\right)$

$\sim 9.8/3^2 \approx 1.1$



9. A 0.200-kg mass attached to a spring whose spring constant is 500 N/m executes simple harmonic motion with amplitude 0.100 m. Its maximum speed is:

A) 25 m/s
B) 5 m/s
C) 1 m/s
D) 15.8 m/s
E) 0.2 m/s

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

$V(t) = \omega A(-)\sin(\omega t + \phi)$

$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{500}{0.2}} = 50$

$V_{max} = \omega A = 50(0.1) = 5\ m/s$

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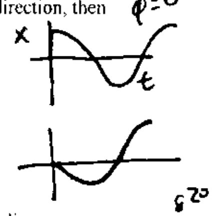
10. A 0.25-kg block oscillates on the end of the spring with a spring constant of 200 N/m. If the system has an energy of 6.0 J, then the amplitude of the oscillation is:
A) 0.06 m
B) 0.17 m
$\boxed{\text{C) 0.24 m}}$
D) 4.9 m
E) 6.9 m

$E_{TOT} = \frac{1}{2} k A^2$
$6 = \frac{1}{2}\, 200\, A^2$
$A = 0.24$ m

11. The displacement of a mass oscillating on a spring is given by $x(t) = A\cos(\omega t + \phi)$. If the initial displacement is zero and the initial velocity is in the negative x direction, then the phase constant ϕ is:
A) 0
$\boxed{\text{B) } \pi/2 \text{ radians}}$
C) π radians
D) $3\pi/2$ radians
E) 2π radians

$x = A\cos(\omega t + \phi)$
$v = -\omega A \cos(\omega t + \phi)$

$\phi = 0$



12. A 3-kg block, attached to a spring, executes simple harmonic motion according to $x = 2\cos(50t)$ where x is in meters and t is in seconds. The spring constant of the spring is:
A) 1 N/m
B) 100 N/m
C) 150 N/m
$\boxed{\text{D) 7500 N/m}}$
E) none of these

$\omega = 50$
$\omega = \sqrt{\frac{k}{m}}$
$50 = \sqrt{\frac{k}{3}}$ $\quad k = 7500$

13. A planet is in circular orbit around the Sun. Its distance from the Sun is four times the average distance of Earth from the Sun. The period of this planet, in Earth years, is:
A) 4
$\boxed{\text{B) 8}}$
C) 16
D) 64
E) 2.52

$T^2 = \frac{GM}{4\pi} r^3$
$\downarrow$
4^3

$T \sim 4^{3/2} = 8$

14. An object attached to one end of a spring makes 20 vibrations in 10s. Its period is:
A) 2 Hz
B) 10 s
~~C) [illegible]~~
D) 2 s
$\boxed{\text{E) 0.50 s}}$

time per vibration $T \approx 10\,\text{sec}/20 = \frac{1}{2}$ sec

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15. Mars has about 1/10 the mass of Earth and about 1/2 the diameter of Earth. The acceleration (in m/s^2) of a body falling near the surface of Mars is about:
A) 9.8
B) 2.0
$\boxed{\text{C) 3.9}}$
D) 4.9
E) none of these

$|F| = G\frac{mM}{r^2} = m\left(\frac{GM}{r^2}\right)$

scaling is: $9.8 \; \frac{1\,(1/10)}{(1/2)^2} \sim 3.9$

16. An astronaut finishes some work on the outside of his satellite, which is in circular orbit around the Earth. He leaves his wrench outside the satellite. The wrench will:
A) fall directly down to the Earth
B) continue in orbit at reduced speed
$\boxed{\text{C) continue in orbit with the satellite}}$
D) fly off tangentially into space
E) spiral down to the Earth

17. In simple harmonic motion, the restoring force must be proportional to the:
A) amplitude
B) frequency
C) velocity
$\boxed{\text{D) displacement}}$
E) displacement squared

18. A particle moves in simple harmonic motion according to $x = 2\cos(50t)$, where x is in meters and t is in seconds. Its maximum velocity in m/s is:
A) $100\sin(50t)$
B) $100\cos(50t)$
$\boxed{\text{C) 100}}$
D) 200
E) none of these

$x = 2\cos 50t$
$v = \underbrace{2(50)(-)}_{V_{max}}\sin 50t$

19. To obtain the absolute pressure from the gauge pressure:
A) subtract atmospheric pressure
$\boxed{\text{B) add atmospheric pressure}}$
C) subtract 273
D) add 273
E) convert to N/m^2

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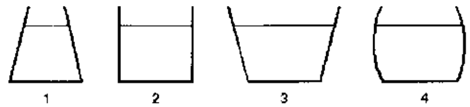
20. The vessels shown below all contain water to the same height. Rank them according to the pressure exerted by the water on the vessel bottoms, least to greatest.



A) 1, 2, 3, 4
B) 3, 4, 2, 1
C) 4, 3, 2, 1
D) ~~2, 3, 4, 1~~
E) $\boxed{\text{All pressures are the same}}$

$\Delta P = \rho g h$

only depends on depth.

21. A rock, which weighs 1400 N in air, has an apparent weight of 900 N when submerged in fresh water (998 kg/m³). The volume of the rock is:
A) 0.14 m³
B) 0.60 m³
C) ~~0.90 m³~~
D) $\boxed{5.1 \times 10^{-2}\ \text{m}^3}$
E) ~~9.2×10^{-2} m³~~

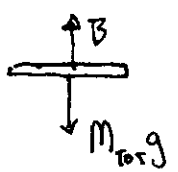
from info $B = 500$ Newtons

$B =$ weight of fluid displaced

$500 = \rho g V$

$500 = 998(9.8)V$

22. The dimensions of a wooden raft (150 kg/m³) are 3.0 m × 3.0 m × 1.0 m. What maximum ***load*** can it carry in sea water (1020 kg/m³)?
A) ~~1350 kg~~
B) $\boxed{7800\ \text{kg}}$
C) 9200 kg
D) 19,500 kg
E) 24,300 kg



$B =$ wgt of fluid displaced

$= \rho g V$

$= 1020(9.8)(3 \cdot 3 \cdot 1)$

$= 9.0 \times 10^4$ Newtons

so

$M_{TOT}\, g = 9.0 \times 10^4$

$M_{TOT} = 9200$ kg

but need to subtract off the mass of the raft itself $150(3 \cdot 3 \cdot 1) = 1350$

$9200 - 1350 = 7850$

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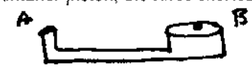
23. A hydraulic press has one piston of diameter 2.0 cm and the other piston of diameter 8.0 cm. If a 100 N force is applied to the smaller piston, the force exerted on the larger piston will be:
A) 6.25 N
B) 25 N
C) 100 N
D) ~~400 N~~
E) $\boxed{1600\ \text{N}}$



$P_A = P_B$

Force/Area = Force/Area

$F_B \sim F_A \dfrac{\text{Area}_B}{\text{Area}_A} \sim 100 \dfrac{8^2}{2^2} = 1600$

24. A lawn sprinkler is made of a 1.0 cm diameter garden hose with one end closed and 25 holes, each with a diameter of 0.050 cm, cut near the closed end. If water flows at 2.0 m/s in the hose, the speed of the water leaving a hole is:
A) ~~2.0 m/s~~
B) $\boxed{32\ \text{m/s}}$
C) ~~40 m/s~~
D) 600 m/s
E) 800 m/s

0.5

0.025

$A_1 v_1 = A_2 v_2$

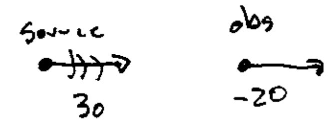
$[\pi(0.5)^2]\,2 = [\pi\ 25(0.025)^2]\, v_2$

$v_2 = 32$

25. The flute and the piccolo are in the same family of instruments, and each functions as a pipe open at both ends. Both have the same fingering but different wavelengths. The flute is about 66 cm long and is an octave lower than the piccolo -- that is, the piccolo plays at twice the frequency of the flute. It follows that the piccolo, in comparision to the flute, is about
A) ~~twice as long~~
B) $\boxed{\text{half as long}}$
C) eight times as long
D) the same length
E) none of these

$f_1 = \dfrac{v}{2L}$

26. You are riding a motorcycle. A car approaches from your rear. At rest, a car's horn produces a 400. Hz tone. If the car approaches at 30. m/s while you ride away from it at 20. m/s, what tone do you hear (in Hz)?
A) 345
B) 389
C) ~~400~~
D) $\boxed{412}$
E) 465



$f = f_0 \dfrac{v + u_{obs}}{v - u_{source}}$

$= 400 \dfrac{343 + (-20)}{343 - (30)} = 400 \dfrac{323}{313}$

$= 413$

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27 In open air, where sound can radiate in all directions, the intensity decreases by how many dB when distance from the source doubles?

A) 2
~~B) 4~~
$\boxed{\text{C) 6}}$
D) 10
E) 12

$dB = 10 \log_{10} \frac{I}{I_0}$

$I \sim \frac{1}{r^2}$

$10 \log \frac{1}{4}$

$-6\ dB$

28. Traveling Waves

Suppose you are dealing with a particular guitar string where the wavefunction is:

$$y(x,t) = 5 \sin (4\pi x - 8\pi t + \pi/2)$$

where y and x are in meters and t is in seconds.

a) Is the wave moving down the +x- axis or the –x axis?

$+x$

b) What in the wavefunction tells you the wave IS moving?

$kx - \omega t$

c) What is the amplitude of the wave?

5

d) What is the wavenumber?

4π

e) What is the angular frequency?

8π

f) What is the wavelength?

$\lambda = \frac{2\pi}{k} = \frac{2\pi}{4\pi} = 1/2\ m$

g) What is the frequency?

$\omega = 2\pi f \Rightarrow 8\pi = 2\pi f \rightarrow f = 4\ Hz$

h) What is the wave speed?

$f\lambda = v$

$4 \cdot \frac{1}{2} = v$

$v = 2\ m/s$

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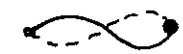
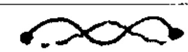
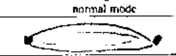
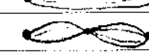
29. Standing Waves

Consider the case of a L-meter long guitar string which is anchored at both ends. In the table below, draw a picture on the shape of the "normal mode" on the string. From this picture, write down the wavelength. Finally, assuming the wave speed is "v", write down an expression for the frequency of each harmonic. The n=1 and n=2 are done as examples.

Harmonic #	Drawing of the normal mode	wavelength	Calculated frequency
1		$2L$	$\frac{v}{2L}$
2		L	$2(\frac{v}{2L})$
3		$2L/3$	$3(\frac{v}{2L})$

Example:

Harmonic #	Drawing of the normal mode	wavelength	Calculated frequency
1		$2L$	$\frac{v}{2L}$
2		L	$\frac{v}{L}$
3			

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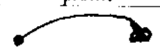
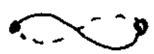
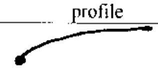
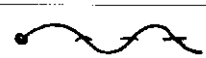
30. Standing Waves

Standing waves in an organ pipe with two open ends. Sketch a picture of the pressure profile in an organ pipe of length L for the first ~~three "normal"~~ modes". Write down an expression for the wavelength of each "normal mode", and provide an expression for the mode's frequency if the speed of sound is "v".

harmonic #	Drawing of pressure profile	wavelength	frequency
1		2L	$\frac{v}{2L}$
2		2L/2	$2\left(\frac{v}{2L}\right)$
3		2L/3	$3\left(\frac{v}{2L}\right)$

31. Standing Waves

Standing waves in an organ pipe with one open end and one closed end. Sketch a picture of the pressure profile in an organ pipe of length L for the first five "normal modes". Write down an expression for the wavelength of each "normal mode", and provide an expression for the mode's frequency if the speed of sound is "v".

harmonic #	Drawing of pressure profile	wavelength	frequency
1		4L	$\frac{v}{4L}$
3		4L/3	$3\left(\frac{v}{4L}\right)$
5		4L/5	$5\left(\frac{v}{4L}\right)$
7		4L/7	$7\left(\frac{v}{4L}\right)$
9		4L/9	$9\left(\frac{v}{4L}\right)$

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