Physics 1520, Fall 2012
Quiz 1, Form: A

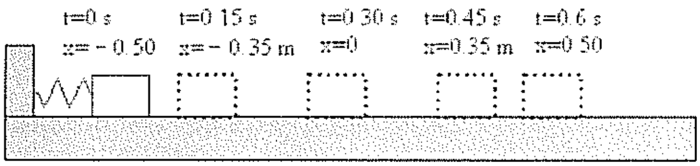
Name: Key
Date:

Unless otherwise stated, the $+x$ axis is defined to the right and the $+y$ axis is defined upward.

Section 1. Exercises

Questions 1–4: Half of a cycle for a 0.25-kg object oscillating in simple harmonic motion is shown below.

x = 0 is equilibrium.



1. What is the frequency?
   - (a) 0.6 Hz
   - **(b) 0.83 Hz**
   - (c) 1.0 Hz
   - (d) 1.2 Hz
   - (e) 1.7 Hz

   $T = 2(0.6s) = 1.2 s$

   $f = \frac{1}{T} = 0.83 Hz$

2. At $x = 0.35$ m, the force by the spring on the object is
   - (a) positive.
   - (b) negative.
   - (c) zero.

   $F_{x\,spring} = -kx$

   $\vec{F}_{spring}$ always points toward equilibrium, so F_x is negative

3. At which time would v_x be the greatest (i.e. most positive)?
   - (a) $t = 0$ s
   - (b) $t = 0.15$ s
   - **(c) $t = 0.30$ s**
   - (d) $t = 0.45$ s
   - (e) $t = 0.6$ s

   at equilibrium, $x = 0$.

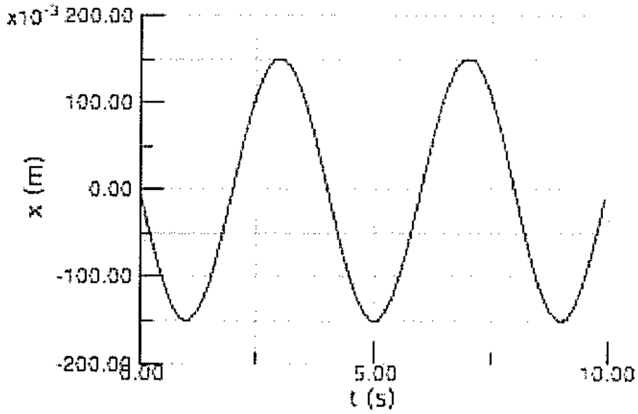
4. At which time would a_x be the greatest (i.e. most positive)?
   - **(a) $t = 0$ s**
   - (b) $t = 0.15$ s
   - (c) $t = 0.30$ s
   - (d) $t = 0.45$ s
   - (e) $t = 0.6$ s

   $\vec{F}_{net} = m\vec{a}$

   so $F_{x\,spring} = ma_x = -kx$

   a_x is most positive when F_x is most positive

Questions 5–6: $x(t)$ for an oscillating mass on a spring is shown below. (Note: the vertical axis is in units of 10^{-3} m.)



5. Approximately how many cycles occur in 10 s?

   (a) 2
   (b) 5
   (c) 3
   (d) 1.5
   (e) 2.5

| 1 cycle | 1 cycle |

6. What is the amplitude of the oscillation?

   (a) -0.15 m
   (b) -0.30 m
   (c) 0.30 m
   (d) 0.15 m
   (e) 3 s

$A =$ peak value of $x = 150 \times 10^{-3}$ m

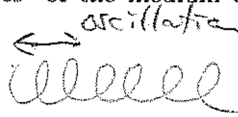
7. A wave on a string is a ______________ wave.

   (a) transverse
   (b) longitudinal
   (c) neither of the above

8. For a longitudinal wave in a medium, the "pieces" of the medium oscillate ______________ to the direction of propagation of the wave.

   (a) perpendicular
   (b) parallel
   (c) neither of the above

oscillation



slinky example

9. The speed of sound in muscle is 1540 m/s. If ultrasound waves of frequency 5 MHz travel through muscle, what is their wavelength? (1 MHz = 1×10^6 Hz)

   (a) 3250 m
   (b) 308 m
   (c) 0.016 m
   (d) 3.1×10^{-4} m
   (e) 6.5×10^{-4} m

$v = \lambda f$

$\lambda = \frac{v}{f} = \frac{1540 \frac{m}{s}}{5 \times 10^6 Hz} = 3.08 \times 10^{-4}$ m

10. A wave on a string travels with a speed of 50 m/s when the tension is 10 N. What is the mass per unit length (i.e. linear density) of the string?

(a) 0.5 kg /m
(b) 2 kg /m
(c) 0.2 kg /m
(d) 0.002 kg/m
(e) 0.004 kg/m

$v = \sqrt{\frac{T}{\mu}}$ $\quad v^2 = \frac{T}{\mu}$ $\quad \mu = \frac{T}{v^2} = \frac{10\ N}{(50\ \frac{m}{s})^2} = 0.004\ \frac{kg}{m}$

11. A 100 W light bulb emits 100 J of light energy per second. At a distance of 2 m from the light, what is the intensity of the light?

(a) 6.0 W/m^2
(b) 50 W/m^2
(c) 2.0 W/m^2
(d) 25 W/m^2
(e) 100 W/m^2

$I = \frac{P}{4\pi r^2} = \frac{100\ W}{4\pi (2m)^2} = 2.0\ \frac{W}{m^2}$ due to pt. source. it spread out over a sphere in space

12. If the intensity of a 100 W light bulb at a distance of 2 m from the bulb is I_0, then at a distance of 6 m from the bulb, the intensity will be:

(a) $1/9I_0$
(b) $1/6I_0$
(c) $1/4I_0$
(d) $1/3I_0$
(e) the same, I_0

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

$I \propto \frac{1}{(3r)^2} = \frac{1}{9r^2}$ so $I = \frac{1}{9} I_0$

13. Suppose that a standing sound wave of harmonic $m = 3$ is set up in a pipe by blowing air across the end of the pipe. The pipe is open on one end and closed on the other. If the speed of sound is 340 m/s and the length is 1.5 m, what is the frequency of oscillation of a "piece" of air?

(a) 300 Hz
(b) 57 Hz
(c) 113 Hz
(d) 340 Hz
(e) 170 Hz

$f_m = \frac{m}{4L} v$ where $m = 1, 3, 5 \ldots$ odd harmonics

$= \frac{3}{4L} v = \frac{3}{4(1.5m)}(340\ \frac{m}{s}) = 170\ Hz$

14. Suppose that Dr. T creates a fundamental standing wave on a long spring (fixed at both ends) by moving his hand up and down with a frequency of 2 Hz. With what frequency will he have to move his hand to achieve the fourth harmonic ($m = 4$)?

(a) 1 Hz
(b) 2 Hz
(c) 4 Hz
(d) 8 Hz
(e) 12 Hz

$f_m = m f_1$

$f_4 = 4(2\ Hz) = 8\ Hz$

15. What harmonic is the standing wave on a string (fixed at both ends) shown below?

6 antinodes

(a) 11th

(b) 3rd

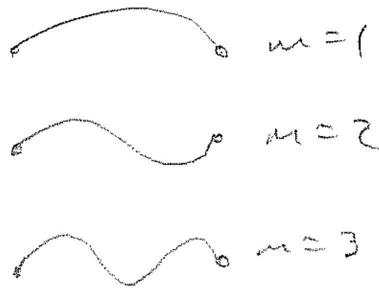
(c) 6th ⭘

(d) 12th

(e) none of the above

antinodes = harmonic

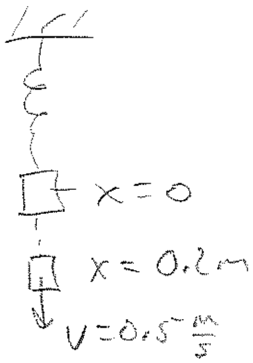
so $n = 6$



Section 2. Critical Thinking

Questions 16–18: You set up a vertical mass-spring system. You hang a 1.6-kg mass on a spring of stiffness 40 N/m and it hangs in equilibrium ($x = 0$). Suppose that you grab the mass and throw it downward. When it leaves your hand, the spring is stretched 0.2 m from equilibrium and has a speed of 0.5 m/s.

16. What is the total energy of the oscillator when it leaves your hand?



$$E = U + K$$
$$= \frac{1}{2}kx^2 + \frac{1}{2}mv^2$$
$$= \frac{1}{2}(40\,\tfrac{N}{m})(0.2\,m)^2 + \frac{1}{2}(1.6\,kg)(0.5\,\tfrac{m}{s})^2$$
$$= 0.8\,J + 0.2\,J$$
$$= \boxed{1.0\,J}$$

17. What will be the amplitude of the oscillation?

$E = \frac{1}{2}kA^2$ at endpoint

$$A = \sqrt{\frac{2E}{k}} = \sqrt{\frac{2(1.0\,J)}{40\,\frac{N}{m}}} = \boxed{0.22\,m}$$

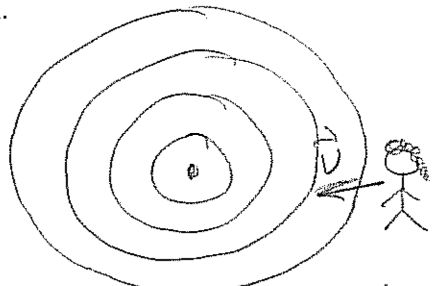
18. What will be the maximum speed of the object as it oscillates?

$E = \frac{1}{2}mv_{max}^2$ at equilibrium

$$v_{max} = \sqrt{\frac{2E}{m}} = \sqrt{\frac{2(1.0\,J)}{1.6\,kg}} = \boxed{1.1\,\frac{m}{s}}$$

19. Suppose that a point source of sound is at rest while a person is moving toward the point source. Will the frequency of the sound heard by the person be greater than, less than, or equal to the frequency of the sound emitted by the source?

Explain your answer without using any equations. Instead, sketch a picture showing circular wavecrests emitted from the source and show the listener moving toward the source. Use this sketch in your explanation.



f heard by the person is greater than f of the source.

As a person is walking she encounters wave crests "faster" than if she is standing still, meaning that the time between wavecrests is less. Thus, T is less. Since $f = \frac{1}{T}$, then f is greater.

20. A bat locates insects by emitting ultrasonic "chirps" and then listening for echoes. The lowest-frequency chirp of a big brown bat is 26 kHz. How fast would the bat have to fly, and in what direction (toward you or away from you), for you to just barely be able to hear the chirp at 20 kHz? 1 m/s = 2.2 mph

Also, comment on whether you think that this speed is possible for a bat to achieve.

$$f_d = \left(\frac{V \mp V_d}{V \pm V_s}\right) f_s$$

If $f_d < f_s$, then the bat must fly away from you. Choose upper sign in the formula.

You are at rest, so $V_d = 0$.

V = speed of sound in air $\approx 340 \frac{m}{s}$

$$20\,kHz = \left(\frac{340 \frac{m}{s}}{340 \frac{m}{s} + V_s}\right) 26\,kHz$$

$$340 + V_s = \frac{26}{20}(340)$$

$$V_s = \frac{26}{20}(340) - 340 = 102\ m/s$$

$$= 102 \frac{m}{s}\left(\frac{2.2\ mph}{m/s}\right) = 220\ mph$$

→ Bat's can't fly this fast!